16.3 ABBOTT, EM*; AZIZI, E; ABBOTT, Emily; Univ. of California, Irvine; *abbotte@uci.edu*

When springs have sprung: tendon recoil rates at different temperatures

Behaviors like chameleon tongue projection, a mantis shrimp punch, or a leaping frog are impressive examples of animal movements. These movements far exceed the mechanical power capacity of skeletal muscle. In order to amplify mechanical power, muscles stretch elastic structures prior to movement. This stores potential (elastic) energy. When elastic structures recoil, the stored energy is rapidly released to amplify power. Evidence for this catapult-like mechanism has been observed in even sub maximal frog jumps and in many species the mechanical power of a jump is well beyond the capacity of hindlimb muscles. If frog jumps are powered through the elastic recoil of tendons and the contraction of muscles is decoupled from the movement of the animal, then we would expect jumping performance to be largely independent of temperature. Yet, frog jump distance improves significantly with increased temperature. This apparent disparity suggests that either the contribution of elastic mechanisms is somewhat limited or that the mechanical properties of tendons have some degree of thermal sensitivity. We hypothesize that the maximum rate of recoil and energy release increase with temperature. To test this prediction we isolated the tendon tissue from bullfrog plantaris muscle-tendon unit. We then applied a 3% stretch to the tendon before rapidly unloading the tendon to measure the speed of recoil and rate of energy release. Experiments conducted at 10, 20, and 30°C show that tendon recoil speed increased significantly ($p<0.05$) with temperature. Thus, these findings suggest that rate properties of tendons do vary with temperature. Therefore, power-amplified behaviors using elastic mechanisms may not be completely insensitive to variation in environmental temperature.

92.6 ABE, H*; AOYA, D; INOUE-MURAYAMA, M; Kyoto University, Akita Prefectural Livestock Experiment Station; *habe2031@gmail.com*

Differently Expressed Genes between Newborn Chicks with Extreme Fear Responses

To better understand the genetic underpinnings of inter-individual difference in fear-induced freezing, it is essential to identify key modulators that are differently expressed in the targeted brain regions. We used newborn domestic chicks to isolate differently expressed genes (DEGs) between individuals with high and low sensitivity to novel fear stimuli. The tonic immobility test was employed to measure the duration of immobilization as an indicator of innate fear response. RNA sequencing technique was used for the rapid identification of up- and down-regulated genes in the amygdala of high-fear chicks as compared with the other brain regions such as the hippocampus and striatum. The top and bottom 10 DEGs included important neurotransmitter-related genes, *e.g.*, *mesotocin/oxytocin receptor* and *arginine-vasotocin/ arginine-vasopressin (AVT/AVP)*. Finally, experimental validation revealed that the relative mRNA expressions of AVT/AVP are significantly different between behavioral groups that showed extreme responses to fear-inducting stimuli. AVT/AVP mRNA expression was significantly higher in chicks with short freezing duration, suggesting different types of coping strategies in response to acute stress between rodents and birds. Our results suggest that AVT/AVP may play a critical role in modulating fear responses by lowering the threshold of risk-taking behavior, as it represents one of the alternative strategies for survival.

P1.120 ABEGAZ, M/F*; GUNDERSON, A/R; SALAS, H; TSUKIMURA, B; STILLMAN, JH; San Francisco State University, University of California Berkley, California State University Fresno , California State University Fresno ; *mabegaz@mail.sfsu.edu*

The Impacts of Density and competition on the reproductive fitness of the intertidal Porcelain Crab, Petrolisthes Cinctipes.

Climate change is expected to contract the habitat range of the upper-mid intertidal porcelain crab, Petrolisthes cinctipes, increasing its population density and elevating behavioral stresses leading to decreased physiological performance. We aim to determine how increased density and competition impacts fecundity, a proxy for reproductive fitness, indexed by circulating levels of the yolk protein vitellogenin. Vitellogenin levels are closely tied to gamete quality and reduced concentrations of it under high-density conditions may result in smaller brood sizes and lower hatching success under future conditions, thereby reducing fitness. Female crabs were exposed either to high- (450 crabs/m2) or low-density (150 crabs/m2) treatments for 14 days. Hepatopancreas, ovary and hemolymph samples were harvested from each crab and analyzed using an ELISA assay to determine vitellogenin concentrations. Results were compared with heat shock proteins expression of individuals to assess degree of cellular stress response associated with cross treatments. We expected vitellogenin concentrations to be higher in low-density (low stress) treatments relative to high-density (high stress) treatments, and for heat shock proteins to have the opposite response. Understanding behavioral responses can will reveal the indirect physiological consequences through shifts in species interactions and population density.

133.5 ABEHSERA, S.*; PELES, S.; AFLALO , ED; SAGI, A.; Department of Life Sciences and the National Institute for Biotechnology in the Negev, Ben-Gurion University of the Negev, Beer-Sheva, Israel; *abehsera@post.bgu.ac.il*

A Novel Protein Family Involved in Mandible Formation in the Decapod Crustacean Cherax Quadricarinatus

Structural-proteins play a key role in extracellular matrix formation. Such an extracellular matrix is the mandible of our study organism *C. quadricarinatus*, a unique cuticular structure which is formed and partially mineralized during pre-molt as opposed to the rest of the cuticle which mineralizes at post-molt. The proteinaceous basis of this process is poorly known. In this study, a novel gene-family encoding Mandible Alanine Rich Structural (MARS) proteins is characterized and suggested to be involved in mandible formation. Our findings are based on a molt-related transcriptomic library originating from the mandible forming epithelia of *C. quadricarinatus*. This protein-family is characterized by an alanine, glutamine and glycine rich repetitive sequences, found also in other known structural proteins. *In silico* and *In vitro* spatial-temporal expression of all four *MARS* genes showed their expression in the mandible forming epithelia during pre-molt. Loss of function experiments using RNAi showed that dsRNA of a member of the family interfered with the transcript level of other members of the family and that silencing caused a dose dependent lethality. In addition, in animals injected with *MARS* dsRNA in parallel to molt-induction, structural deformities were detected in the incisor. Homologues MARS proteins with a high degree of conservation were found in other crustaceans. In this study, a newly found structural-genes family unique to crustaceans is characterized and suggested to have a role in mandible-formation in a decapod crustacean. Thus, providing for the first time insights into the proteinaceous basis of mandible-formation in crustaceans.

P3.142 ABNEY, CJ*; EERNISSE, DJ; VENDETTI, JE; California State University, Fullerton, Natural History Museum of Los Angeles County, California; *jabney1993@gmail.com*

How are SoCal natives? Current status of southern California helicoid land snails (Helminthoglypta) using historical records and DNA sequencing.

The land snail genus, *Helminthoglypta* (Helminthoglyptidae), accounts for about 24% (68 of 284) of recognized native California terrestrial gastropod species. Despite patterns of endemism along California's coast, this genus has been relatively ignored in the wake of Henry Pilsbry's extensive and influential 1939 monograph. Notably, there have been almost no DNA-based studies for *Helminthoglypta*, not uncommon among North American land snail genera. Morphological studies and species delimitation can be challenging because the diagnoses of Pilsbry and others rely on subtle anatomical and shell differences, while specialists who are adept at differentiating these species have long been in decline. In this study, *Helminthoglypta* species were collected from the heavily urbanized Los Angeles and Orange Counties, and subjected to both molecular analysis and conventional morphological identification. Mitochondrial (COI, 16S) gene regions were successfully sequenced and nuclear markers are being explored for informative variation. We are relating these results to a survey of current habitat availability by comparing locality data from historical museum records with field observations using GIS-based distribution maps. This survey is a step towards assessing the impact of urbanization on members of *Helminthoglypta*, and targeting imperiled species for future conservation efforts. A major goal of this effort is to make these snails more accessible to non-experts for future studies on this genus.

139.3 ABOLINS-ABOLS, M*; KASSAB , H/D; KETTERSON, E/D; ABOLINS-ABOLS, Mikus; Indiana University; *mabolins@indiana.edu*

Hormone and melanocyte signaling in a social feather ornament

Bird feathers are one of the most striking examples of variation in nature. Some of the variation in feather ornaments has been shown to act as a signal of the status or quality of an individual. To understand why and how particular ornaments are used as social signals, we must understand the factors that regulate their development. Hormones, such as estrogen and testosterone, have been shown to regulate sex differences in feather color. Here we asked if feathers that form a melanin-based ornament used in attracting mates and signaling status - the white outer tail feathers of Dark-eyed junco (*Junco hyemalis*) - are sensitive to testosterone and estrogen, and if hormonal signaling explains variation in the extent of white in junco tails. We used qPCR to measure the expression of androgen receptor (AR) and estrogen receptor (ER), and compared receptor abundance among males that showed different amounts of tail white. Furthermore, we asked if hormone receptor expression was correlated with expression of key melanocyte signaling markers agouti signaling peptide (ASIP) and melanocortin 1 receptor (MC1R). Our results show individuals with more tail white express more MC1R and marginally more ASIP. While individual variation in feather color was not directly related to hormonal sensitivity, ASIP expression was significantly positively correlated with both AR and ER expression. Our results show that developing feathers that form social ornaments are sensitive to hormones, and provide a mechanistic hypothesis for the link between the size of the ornament and the status or quality of an individual.

25.4 ABZHANOV, ARKHAT; Imperial College London and Natural History Museum; *a.abzhanov@imperial.ac.uk*

Evolution of the Animal Face: from Principles to Mechanisms.

Understanding the origins of animal diversity is one of the chief challenges to the modern biological sciences. We aim to reveal molecular mechanisms underlying evolutionary processes that generate morphological variation, and to show how particular changes in embryonic development can produce morphological alterations for natural selection to act upon. The principal focus for our studies is on the animal face and head. Cranial diversity in vertebrates is a particularly inviting and challenging research topic as animal heads and faces show many dramatic, unique and adaptive features which reflect their natural history. Most of the facial diversity depends on the shapes and sizes of the bones and cartilages that make up the cranial skeleton. I will describe how our investigations of craniofacial skeletal development in amniote animals are helping us to uncover mechanisms that generated cranial diversity during evolution. In particular, we employ a synergistic combination of morphometrics techniques, comparative molecular embryology and functional experimentation methods to trace cranial evolution in birds and mammals, some of the most charismatic groups on our planet.

124.5 ACKERLY, KL*; CHAPMAN, LJ; KRAHE, R; McGill University; *kerri.ackerly@mail.mcgill.ca*

The Effects of Hypoxia on Fast-starts and Electric Signal Production in the African mormyrid, Gnathonemus victoriae

Most fishes perform stereotyped fast-start responses to escape predation when threatened, and a fish's ability to perform these responses can directly affect survival. As a result, individuals should be able to maximize fast-start performance even under physiologically limiting conditions such as hypoxia (low dissolved oxygen (DO) concentration). Previous studies have shown the anaerobic locomotor performance of fast-starts can be largely unaffected by hypoxia, but suggest that hypoxia negatively affects the aerobic non-locomotor aspects of fast-starts (e.g., directionality) that rely on a fish's ability to sense their environments. However, research on these effects is limited because of the difficulty of quantifying how an individual senses their environment. To address this issue, we used a weakly electric fish (*Gnathonemus victoriae*) as a model system because the electric signals they produce to sense their environments can be non-invasively quantified in free-swimming individuals. In this study, we acclimated *G. victoriae* to either high or low DO levels for 8 weeks, and subsequently quantified fast-start performance along with electric signal production under high- or low-DO test conditions. Locomotor performance of fast-starts (e.g., displacement) was largely unaffected by low-DO test conditions regardless of acclimation. However, individuals acclimated to high-DO conditions had reduced electric signal production under low-DO test conditions. Our results suggest that exposure to acute hypoxia compromises the ability of fish to sense their environment during fast-starts; however, acclimation reduced the negative effects of hypoxia on performance.

P1.252 ACKERLY, KL*; MITROFANOV, I; SANFORD, CP; KRAHE, R; CHAPMAN, LJ; McGill University, Hofstra University; *kerri.ackerly@mail.mcgill.ca*

The Relationship Between Body Morphology and Swim Performance Among Mormyrid Elephant Nose Fishes

Swim performance in fishes is influenced by body morphology, which is often reflective of the natural environment. For example, fish living in high-flow environments (e.g., river rapids) typically have streamlined bodies and fins designed for steady swimming, while fish from low-flow, structurally complex environments (e.g., swamps) typically have maneuverable bodies and large fins that aid in unsteady swimming. These factors can also be influenced by phylogenetic relationships among species. To obtain a comprehensive understanding of the influence of natural habitat on morphology and swimming performance, we investigated the relationship between morphology and swimming performance among three closely related species of wild-caught elephant nose mormyrid fishes from divergent habitats. Geometric morphometrics was used to characterize differences in body and fin shapes among a high-flow species (*Campylomormyrus* spp.), an open-water species (*Gnathonemus petersii*), and a swamp species (*Gnathonemus victoriae*). We also determined the swimming capabilities of each species at four swim speeds (0.5-2.0 body lengths/sec). While our results indicate that morphological differences among species are reflective of their natural environments (e.g., high-flow species are more streamlined than swamp species), our swim performance findings are contrary to our predictions. The high-flow species, *Campylomormyrus* spp., spent significantly more time swimming unsteadily at every speed compared to both *Gnathonemus* species. This can be explained, in part, by differences in the head and snout shape among the three species, which may have a greater influence on swimming patterns than overall body shape.

P3.250 ACKLES, AL*; HERNANDEZ, LP; George Washington University; *alackles@gwu.edu*

Hypertrophy of the Cypriniform Pharyngeal Jaw: Growth Patterns of Branchial Arches within Cypriniforms and their Relatives

In teleost fishes, the most posterior branchial arches form a highly modified feeding apparatus known as the pharyngeal jaws. The 3rd and 4th pharyngobranchials form the upper pharyngeal jaw while the 5th ceratobranchial forms the lower pharyngeal jaw. Cypriniformes in particular have undergone further modifications to their feeding morphology, including extreme hypertrophy of the lower pharyngeal jaw and loss of the upper pharyngeal jaws. While in more basal telosts the ceratobranchials decrease in size anterior to posterior, the cypriniform fifth ceratobranchial is often significantly larger than the preceding ceratobranchials. How this hypertrophied fifth ceratobranchial develops throughout ontogeny in comparison to ceratobranchials 1-4 has not been carefully studied. To investigate the possible developmental mechanisms behind this modified morphology, we compared the ontogeny of a cypriniform pharyngeal jaw (*Danio rerio*) with the ontogeny of the pharyngeal jaws of more basal related species (*Anchoa mitchilli* and *Brevoortia tyrannus*). Here we present comparative data from morphometric analyses of the ceratobranchial arches in larval to adult specimens of *D. rerio*, *A. mitchilli*, and *B. tyrannus*. We find that multiple heterochronic events, including sequence and rate of chondrogenesis, sequence and rate of ossification, and overall growth of the ceratobranchials, may contribute to the greatly hypertrophied fifth ceratobranchial. These data provide a glimpse at a few potential ontogenetic pathways to morphological innovations.

P2.242 ADAM, KM*; CLARK, RM; WILLIAMS, CM; Univ. of California, Berkeley; *katelynadam1@berkeley.edu*

Circadian Organization of Hemolymph Content and Volume in association with Juvenile Hormone in a Flight Capable field cricket, Gryllus firmus

Temporal organization is an important aspect of organismal biology, yet little is known about the nature of this variation within populations. We examined temporal variation in hemolymph characteristics in a cricket species with genetically-based differences in circadian fluctuation of juvenile hormone(JH). Circadian fluctuation in JH is thought to regulate the temporal aspects of reproduction and locomotor behavior in insects. If the circadian fluctuation in JH regulates metabolic processes, we would expect to observe correlated changes in hemolymph metabolites. Specifically, morphs with differing JH chronotypes will exhibit hemolymph profiles reflective of their life history patterns. We measured total hemolymph macronutrient content and concentration across the circadian cycle at five time points in five day old female *Gryllus firmus*.Hemolymph content was quantified using standard biochemical assays, while volume was determined by injection and recovery of a FITC-inulin solution. Overall, the flight capable morph (FC) maintained constitutively lower hemolymph volumes. The FC morph also had higher total lipid content and concentration, which increased toward the evening. There were no significant differences in carbohydrate and protein concentration between morphs, nor did concentrations fluctuate. However, the flightless reproductive morph had higher total protein and carbohydrate amounts. This supports the claim that the JH titer acts as a priming signal for lipid mobilization in FC morphs. Therefore temporal organization of hemolymph volume and content support the physiological and metabolic demands associated with life history patterns like flight preparation.

P1.247 ADAMS, DA*; GALLAGHER, EE; GOUGH, WT; TENNETT, KT; FISH, FE; West Chester University; *da762671@wcupa.edu*

Passive Spanwise Flexibility of Harbor Porpoise Flukes: Equivalence of Dorsal and Ventral Flexion

The flukes of cetaceans are the principal structure used to generate thrust during swimming. The flukes are composed of a compact array of collagen fibers with a complex organization. This arrangement provides the flukes with both rigidity and flexibility. There has been disagreement regarding the contribution of the up- and down-stroke of the flukes to swimming. To assess the baseline passive flexibility of the flukes and determine if bending is equal between dorsal and ventral orientations, the flukes of 11 mature harbor porpoises, *Phocoena phocoena*, were subjected to a single point bending test. An isolated fluke was immobilized at its base and increasing increments of weight (up to 1.8 kg) were suspended for the tip of the fluke. Scaled images were taken for each increment of weight to measure the deflection of discrete points along the span of the fluke. Deflection along the fluke span increased curvilinearly to a maximum at the tip of the fluke. This flexibility would be dependent on the tapering spanwise profile of the fluke, internal fiber direction, and its differential composition density. There was no difference in flexibility between flukes in a dorsal or ventral orientation. This correlates with the dorso-ventrally symmetrical internal fibrous structure of the flukes. These data suggest that the morphology of the flukes is aligned with a symmetrical up- and down-stroke.

P3.135 ADAMS, CIM*; HOEKSTRA, LA; MUELL, MR; JANZEN, FJ; Iowa State University; *ciadams@iastate.edu*

The painted turtle (Chrysemys picta) as a model for environmental DNA (eDNA) monitoring of imperiled aquatic reptiles

Current conservation methodology relies on the detecting of endangered species, thus it is imperative to identify efficient and effective ways to monitor such populations. Environmental DNA (eDNA) provides scientists with potentially revolutionary techniques for observing target populations - especially when time and resources are limited. However, despite an emerging body of presence/absence eDNA literature, eDNA remains underdeveloped as a quantitative measure for endangered species populations. To remedy this issue, we used eDNA to estimate population biomass for the painted turtle *(Chrysemys picta)* as a model for endangered freshwater turtle species. We seeded isolated semi-natural ponds with 0, 11, 20, and 38 adult turtles from 1 April 2015 and regularly obtained water samples from the ponds through 30 June 2015. We noted a pattern of increased general eDNA with time as turtles were present in the habitat (p-value < 0.001; F-value $= 6.21$), but detected no significant relationship between turtle biomass and quantity of general eDNA in the water samples. We discuss potential confounders of these relationships and their implications for using eDNA to monitor aquatic turtles. Only through further development can eDNA be used effectively for the conservation of wild aquatic reptile populations.

P3.123 ADAMS, AM*; PINSHOW, B; Texas A&M University, Ben-Gurion University of the Negev; *aadams@bio.tamu.edu*

Scorpions modify their behavior and burrow structure in response to the physical environment

Many animals reside in burrows that serve as refuges from predators and from adverse environmental conditions. Because burrows are integral parts of the lives of fossorial and semi-fossorial animals, they can be construed as extensions of the organism's own physiology (*sensu* Turner 2000). Little is known about how the sequestered burrow environment meets the physiological needs of its occupant(s). *Scorpio palmatus* burrows are tortuous, with at least two bends, and have a horizontal entrance platform near the ground surface. We hypothesized that the burrow acts as an extension of the animal's physiology, with the burrow architecture regulating air flow and temperature fluxes between the occupant and the ambient environment. We found that entrance size, not burrow tortuosity, affects burrow ventilation, the smaller the entrance diameter, the less the ventilation. *S. palmatus* dug wider tunneled, more tortuous burrows in dry soils compared to those dug in wet and semi-dry soil. Also, *S. palmatus* can apparently influence their internal body temperature by tracking temperature gradients within their burrows. We tracked scorpion behavior with infrared video and PIT tags and found that a platform just after the burrow entrance provided a place to spend much of the night and day, with scorpions spending more time on the platform during the day than predicted. Overall, we found that *S. palmatus* modifies its behavior and burrow structure in response to the physical environment.

P1.35 ADAMS, S.L.*; FURIMSKY, M.M.; Westminster College; *adamsl22@wclive.westminster.edu*

The Effect of Masking the Parietal Eye on Normal Baseline Behaviors Regarding Light (UVb) and Heat Preference of the Bearded Dragon Pogona vitticeps and the Green Anole Anolis carolinensis

The parietal eye is a photosensitive structure with a well-developed cornea, retina, and lens, located on the top of the head in some species of lizards. In combination with the pineal complex above which it is located, the parietal eye plays a role in the secretion of melatonin which is important for the lizard to be able to regulate awake/sleep cycles as well as thermoregulation. The secretion of melatonin is dependent on the ability of the parietal eye to sense UVb rays. When the parietal eye is removed or covered, there are significant alterations in the lizard's ability to thermoregulate both behaviorally and physiologically. Our research question focused on the effect of masking the parietal eye on normal baseline behaviors regarding light (UVb) and heat preference of the bearded dragon *Pogona vitticepes* and the green anole *Anolis carolinensis*. The objectives of our research were to observe basking behavior under UVb and infrared heat light and to determine the amount of time spent under each bulb, under normal baseline behaviors and when light detection by the parietal eye of all subjects was inhibited with a non-toxic black paint. The black paint disrupted the light signal from reaching the parietal eye, and the light information was not processed by the pineal complex, hence disrupting normal baseline behaviors. Basking time data was collected from a video camera which recorded the lizards activity during the day. Baseline behaviors including locomotor activity only before and during feeding were observed every hour for a week. Masking the parietal eye disrupted the stereotypical baseline behaviors observed in both species of lizard, demonstrating the importance of this sensory structure to the everyday physiological needs of these animals.

107.1 ADAMS, AM*; POCOCK, J; SMOTHERMAN, M; Texas A&M University; *aadams@bio.tamu.edu*

Modelling mutual suppression of sonar in groups of bats

How bats mitigate mutual interference is a longstanding question that has both ecological and technological implications as biosonar systems continue to outperform man-made sonar systems in noisy, cluttered environments. Groups of echolocating bats coordinate their biosonar through mutual suppression, slowing their pulse emission rates when flying in groups to reduce interference and improve sonar performance. We constructed a computational model of the Brazilian free-tailed bat's (*Tadarida brasiliensis*) biosonar behavior that incorporates a flexible transmission delay algorithm to investigate how parameters might be optimized for groups of different sizes or while performing different tasks. This artificial back-off algorithm is a non-homogenous Poisson-based back-off algorithm that generates delays similar to those observed in bats hearing another bat's pulse emissions. We compared our modeled results with the empirical measures of pairs and trios of *T. brasiliensis* flying together in a flight room and found that emission rates were context-dependent in a manner consistent with the hypothesis that the bat's back-off algorithm may be adjustable based on group size, orientation, and task. This has significant implications for current technologies because the algorithms used in modern artificial devices (cell phones, wireless internet, etc.) lack the ability to adapt in real-time to network load and usage patterns. Decoding the bats social sonar algorithms may thus provide a biologically-inspired model of a fast, efficient and stable networking protocol that can improve emerging technologies and artificial communication networks protocols.

P1.112 ADHAV, A/A*; REITZEL, A/R; MCALISTER, J/S; College of the Holy Cross, Univ. of North Carolina at Charlotte; *aaadha17@g.holycross.edu*

Maternal provisioning of eggs of the starlet sea anemone, Nematostella vectensis: Selection pressures favoring the evolution of coloniality

The success over evolutionary time of lineages with colonial organizations (e.g. cnidarians) is substantial. Coloniality has only evolved in a few lineages however, suggesting specific selection pressures that favor this life history mode. To test hypotheses for why coloniality may have evolved, we are examining gene expression and physiological energetic differences between solitary and experimentally manipulated colonial morphotypes of the starlet sea anemone, *Nematostella vectensis*. Coloniality may confer specific reproductive advantages, such as increases in the quantity or quality of offspring, when compared with solitary individuals. Offspring of better quality may be produced, for example, when mothers provision eggs with biochemical constituents with greater organic content and/or per unit energy, such as lipid and protein. We measured per egg levels of maternal provisioning using standard colorimetric assays of total lipid and protein content for eggs produced by solitary and two-headed (colonial) morphotypes of *N. vectensis*. Our results from these assays reveal significant differences between morphotypes in per-egg organic and energetic contents and densities. Our results indicated that one-headed individuals produced eggs that were significantly more energy-rich. Alternatively, two-headed individuals produced significantly more and larger eggs, each containing significantly less lipid and protein. We will discuss these results in light of their effects on offspring quality, development, and growth, as well as their implications for the selection pressures favoring the evolution of coloniality.

P1.202 ADITY, RIFAT*; NISHIKAWA, KIISA; Northern Arizona University; *ra675@nau.edu*

The Effect of Prior Shortening On Residual Force Enhancement After Stretch

The mechanism of muscle contraction was first explained by the sliding filament theory. However, Force enhancement after stretch is a long know but poorly understood property of active muscles and can be poorly explained by this theory. Recently, a new theory of muscle contraction, the winding filament hypothesis (WFH) has been suggested. This hypothesis explains how titin acts in conjunction with sliding filament theory. Many theories have been proposed to account for force enhancement, including the idea that an elastic element forms in muscles upon activation. If activation of a passive elastic element is responsible for force enhancement, then shortening prior to stretch should reduce the extra force upon stretch. Previous research included experiments in which active muscles were shortened prior to stretch and observed no reduction in residual force enhancement (RFE) and it was observed when pre-shortening preceded stretch by ~1 second. The conclusion was that, if an elastic element is formed in muscle during activation, it is not slackened by shortening. The purpose of this study was to evaluate the effect of a delay between shortening and stretch on RFE in mouse soleus muscles. Muscles were placed initially on the descending limb of the force-length relationship. The muscles were first shortened and then stretched at a fixed amplitude (10% fiber length) and speed (40% fiber length/s), either immediately following shortening, or 100, 200, 300, 400 or 500 ms following shortening. As the interval between shortening and stretch increased, RFE increased up 300 ms, and declined thereafter. These observations are consistent with the idea that a passive structural elastic element, possibly titin, develops upon muscle activation in vertebrate skeletal muscle. These findings are consistent with the predictions of the WFH.

64.7 ADJERID, K*; PENDAR, H; DE VITA, R; SOCHA, JJ; Virginia Tech; *adjerid@vt.edu*

Predicting the mechanical response of (Zophobas morio) tracheal tubes to hemolymph pressure

Insects breathe using a complex network of tracheal tubes, parts of which rhythmically compress in some species, facilitating active ventilation. Previous studies suggest that hemolymph pressures of 1-2 kPa may induce tracheal tube collapse in beetles. However, it is not known if pressure alone induces collapse, or if other physiological processes are at play. Considering the tracheal system as an isolated mechanical system, we ask, do tracheal tubes respond to fluid pressure as thin-walled cylinders? If so, their response can be predicted using an analytical thin-walled cylinder model, which assumes the tubes to be long, thin, and circular, with elastic and isotropic walls. We used atomic force microscopy (AFM) to measure elastic moduli and microtome sectioning to determine thicknesses of tracheal tubes throughout the tracheal system. To determine collapse pressures of tracheal tubes in sacrificed beetles (n =11), we manually increased hemolymph pressures to physiologically-relevant maxima (~2 kPa, in the thorax) while simultaneously recording tube collapse using synchrotron X-ray imaging at Argonne National Laboratory. We found that smaller tubes required greater collapse pressures than larger tubes, with values ranging from 0.3-0.6 kPa. Preliminary AFM results revealed an elastic modulus on the order of ~2 GPa, and sectioning showed that the thicknesses of the tracheae ranged between 4-25 µm for tubes with diameters of 10-200 µm. Using these values, the model predicts an inverse relationship between collapse pressure and diameter, with larger tubes requiring less pressure for collapse, congruent with the values obtained with X-ray imaging. These results support the hypothesis that tracheae collapse in response to hemolymph pressure during rhythmic compression. Supported by NSF 1558052.

103.5 AGOSTA, SJ*; JOSHI, KA; KESTER, KM; Virginia Commonwealth University; *sagosta@vcu.edu*

Upper Thermal Tolerance Differs Among Component Species in a Host-Parasitoid-Hyperparasitoid System

Upper thermal tolerance has been measured for many species and is thought to be a useful physiological parameter for assessing vulnerability to climate change. Despite this, few studies have actually compared the upper thermal tolerances of ecologically-linked species, such as between parasites and their hosts. Given variation in thermal tolerance, climate change may affect species differently, with significant consequences for the dynamics of trophic interactions. In this study, we compared upper thermal tolerance in a tri-trophic system including a caterpillar (*Manduca sexta*), a parasitoid wasp (*Cotesia congregata*), and a hyperparasitoid wasp (*Spilochalcis* spp.). We measured the critical thermal maximum (CT_{max}) of component species, as defined by the temperature at the onset of involuntary muscular spasms. Individuals were collected in the wild from a single tobacco field in south central Virginia, USA. We found that CT_{max} varied significantly among species: the parasitoid *C. congregata* had the lowest CT_{max} (mean ± SE = 42.8 ± 0.2 °C, n = 16 individuals), the hyperparasitoid *Spilochalcis* spp. had the highest (48.3 ± 0.3 °C, n = 10), and the caterpillar *M. sexta* was intermediate between these two (46.5 ± 0.2 °C, n = 23). This mismatch in upper thermal tolerance among component species may have important implications for the ways this and other host-parasite systems respond to climate change.

_P1.98_ AGOSTO, L/M*; HELM, B/R; HOLTHUSEN, J; TORSON, A/S; YOCUM, G/D; GREENLEE, K/J; BOWSHER, J/H; University of Central Florida, North Dakota State University, USDA-ARS Animal Metabolism-Agricultural Chemicals, USDA-ARS Insect Genetics and Biochemistry; *laurie.agosto@knights.ucf.edu*

Hacking the Solitary Bee: Connecting Hormonal Dynamics with Underlying Molecular Mechanisms During Development

Insects—especially holometabolous—undergo a complex metamorphosis in form and function from the immature to mature stage of their life cycle. Physiologically, metamorphosis is regulated by hormones, primarily juvenile hormone and ecdysone, which control different aspects of the metamorphic processes[1-3]. However, much of our understanding of metamorphosis is based upon studies focusing on just a few model organisms, and connections between the physiological dynamics and their underlying molecular mechanisms remain poorly described[1-3]. Here, we simultaneously characterize the developmental physiology and corresponding molecular mechanisms of larval to adult metamorphosis in the alfalfa leaf cutter bee, *Megachile rotundata*. We measured the hemolymph titer of juvenile hormone III (JHIII) using a recently established HPLC-MSMS protocol[4]. From these same individuals, we quantified the expression of genes that regulate JHIII synthesis, degradation, and reception in target tissues. While we did not directly assay ecdysone quantities in hemolymph for this study, we quantified expression of genes that regulate its synthesis and reception. This research integrates physiology with the molecular mechanisms underlying insect metamorphosis.

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Hacking the solitary bee: connecting hormonal dynamics with underlying molecular mechanisms during development

Insects—especially holometabolous—undergo a complex metamorphosis in form and function from the immature to mature stage of their life cycle. Physiologically, metamorphosis is regulated by hormones, primarily juvenile hormone and ecdysone, which control different aspects of the metamorphic processes. However, much of our understanding of metamorphosis is based upon studies focusing on just a few model organisms, and connections between the physiological dynamics and their underlying molecular mechanisms remain poorly described. Here, we simultaneously characterize the developmental physiology and corresponding molecular mechanisms of larval to adult metamorphosis in the alfalfa leaf cutter bee, *Megachile rotundata*. We measured the hemolymph titer of juvenile hormone III (JHIII) using a recently established UHPLC-MS/MS protocol. From these same individuals, we quantified the expression of genes that regulate JHIII synthesis, degradation, and reception in target tissues. While we did not directly assay ecdysone quantities in hemolymph for this study, we quantified expression of genes that regulate its synthesis and reception. This research integrates molecular mechanisms with overarching patterns in hormones controlling insect metamorphosis.

_P2.53_ AGUILAR, M. A.*; OAKLEY, T. H.; Univ. of California, Santa Barbara; *aguilar@lifesci.ucsb.edu*

Target Practice: Challenges of Targeted Gene Capture of Highly Conserved Genes

While using methods of genomic-DNA targeted gene capture to build a phylogeny of chitons, we encountered challenges within the protocols. Gene capture methods aim to sequence highly conserved gene regions of interest from genomic libraries using oligo probes and high throughput sequencing. The method is just now becoming more commonly used in non-model organisms. Although gene capture promises an efficient protocol for massively paralleled sequencing, we here address several hurdles and how to overcome them. First, small amounts of DNA are a challenge. Therefore, optimizing genomic DNA extractions is important to ensure that there is an abundance of gene fragments of interest, which should increase the probability of gene capture. Second, the presence of adapter-dimers—a common artifact from Illumina genomic library preparation—complicates the gene capture because the probes can non-specifically bind to them. Quality control via Bioanalyzer or TapeStation can reveal the adapter-dimers and size selection of DNA fragments can remove adapter-dimers. A third hurdle involves the optimization of the hybridization temperature between probe and gene target. We find it is important to heat denature the gene fragments at 98°C and slowly cool down to 65°C to enable the hybridization of single stranded gene targets and the probe. Lastly, figuring out how much sequencing coverage is needed per sample can be an ambiguous hurdle. A gene capture does not necessitate as many sequencing reads as a single transcriptome for example. One can calculate how much coverage one needs according to the number and length of the conserved genes of interest that the probes were designed from. It is necessary to discuss these challenges to minimize time and monetary costs while troubleshooting the multifaceted gene capture protocol for non-model organisms.

_22.2_ AHMED, OM*; MANOLI, DS; TUN, KM; SERPA, P; CHENG, J; KNAPP, JM; STERN, DL; SHAH, NM; Univ. of California, San Francisco, Janelia Research Campus; *osama.ahmed@ucsf.edu*

Evolutionary Mechanisms that Inhibit Interspecies Mating in Drosophila

A key tenet of evolutionary theory is that even closely related species remain reproductively isolated. Indeed, inter-species hybrids are rarely found in the wild. This reproductive isolation extends to the behavioral level, as even closely related species do not attempt to mate with each other. This suggests that genetically hardwired mechanisms enforce such isolation. Male fruit flies of at least three different species use the foreleg, a sensory organ, to inhibit inter-species mating. Gr32a, a chemoreceptor expressed in the foreleg of *D. melanogaster*, is required to detect inhibitory pheromones of other Drosophilid species in order to preclude inter-species mating. Moreover, Gr32a+ neurons are necessary and sufficient to inhibit such behavior. Given that the sensory pathway for inhibiting inter-species mating is conserved, we are using modern genetic tools to understand how the neural circuits underlying mate choice have evolved in disparate fly species. We generated novel transgenic lines in *D. melanogaster* and other fly species to determine whether Gr32a functions in an analogous manner across species. These studies involve examining the control of Gr32a expression and its function in different species. Taken together, my studies will lead to a better understanding of how behavioral reproductive isolation has evolved.

P3.36 AHRARI, A; KHODABANDEH, S*; AKHAVAN NIAKI , H; Univ. of Tarbiat Modares, Univ. of Babol; *surp78@gmail.com*

Anti tumoral effects of Persian Gulf puffer fish (Chelonodon patoca) tetrodotoxin in Balb/c nu mice

The goal of this study was investigating the antitumor effects of tetrodotoxin extracted from puffer fish, Chelonodon patocaThe goal of this study was investigating the antitumor effects of tetrodotoxin extracted from puffer fish, *Chelonodon patoca* on *Balb/c nu* (as a model for breast tumor). Fish samples were collected from inter tidal area of Qeshm Island (Persian Gulf) and transported to the laboratory in nitrogen tank. Liver and ovary extracts were prepared by methanol-acetic acid 2%. In order to determine the lethal concentrations of TTX, particular concentrations of extractions were prepared. Then they were injected into cancerous Balb/c nu (via 4T1 cell line). Tumor volume growth rates were recorded by vernier calipers. Following rearing 3-4 weeks, the mice were dissected for removing their tumors. A part of tumors was fixed in Buain's solution for histological and immunohistochemistry studies. Some parts of tumor were stored in -80 oC further biochemical examinations. Biometry analysis showed that tumor growth rate percentages in TTX injected group were significantly lower in comparison to control group. Also, microscopic studies revealed that Na+,K+-ATPase levels in tissue of TTX injected mice were significantly lower than control group. These results showed that TTX extraction may be causes decreasing tumor growth rate by of sodium potassium pump. Recent study showed that growth rate of tumor was decreased by Na+, K+-ATPase inhibitors. In the present study result shows that TTX extraction decreased intensity and activity of Na+- K+-pump. Therefore, it can act as Na+- K+-pump inhibitor and finally decrease growth rate of tumor.

124.2 AIELLO, BR*; BENSMAIA, SJ; HALE, ME; Univ. of Chicago; *braiello@uchicago.edu*

Encoding properties of pectoral fin mechansensors in response to fin deformation

Mechanosensory feedback has been shown to be critical to motor performance of vertebrate limbs. In fishes, the pectoral fin performs dual roles as a propulsor and a sensor. Although fins are known to be mechanosensitive, much remains to be discovered about how fin deformations are encoded in afferent responses. Here we use a suite of mechanical stimuli along spatiotemporal axes to probe the stimulus features encoded by the pectoral fin afferents of *Gomphosus varius*. We examine the dependence of response strength and dynamics on stimulus amplitude and examine the frequency sensitivity of individual afferents, both in the strength and phase-locking of the response to vibratory stimuli over a range of amplitudes and frequencies. Movements are encoded by afferents that can be classified as rapidly or slowly adapting, responding only during the transient phase of a stimulus, or as afferents that exhibit both adaptation properties. Our data indicate that different afferents also exhibit different frequency sensitivity profiles, with some afferents responding to frequencies greater than 20Hz, which exceeds the range of typical fin beats. Many of these afferents also exhibit precise phase-locking to vibratory stimuli across a wide range of frequencies. These data enhance our understanding of the mechanical features being encoded by pectoral fin afferents. The high temporal precision and the ability to encode frequencies well above normal fin beat frequency suggest that pectoral fin mechanosensory feedback may be used for other purposes in addition to its role in modulating fin movements and motor patterns.

P1.208 AIELLO, BR*; HARDY, AR; OLSEN, AM; CHERIAN, C; AHN, SE; HALE, ME; WESTNEAT, MW; Univ. of Chicago; *braiello@uchicago.edu*

The impact of fin ray morphology on pectoral fin flexural stiffness in labriform swimmers

The mechanical properties of an appendage influence its propulsive capabilities. In labrid fishes, which employ pectoral fin-based propulsion ranging from rowing to flapping, the fins of flappers are nearly an order of magnitude stiffer than rowers. Also, fin ray stiffness decreases along a fin's proximodistal span and across the fin's chord from the leading to trailing edge. The flexural stiffness of a simple structure is a product of its material's Young's modulus (E) and its second moment of area (I). However, fin rays are complex structures that are typically branched and segmented distally. To examine the impact of fin ray morphology on stiffness, we quantified intrinsic pectoral fin ray stiffness in similar-sized fins of two closely related species, the flapping *Gomphosus varius* and the rowing *Halichoeres bivittatus*. We measured each fin ray's E, I, unsegmented length, segments per unit length, average segment length, branching pattern, and the percent fin coverage by ray versus membrane (ray density). Within each species, bivariate analyses revealed that I, unsegmented length, average segment length, and number of segments per unit length were all significantly correlated with ray stiffness; E did not correlate with stiffness, but was significantly greater at 83.2% fin ray length in comparison to more proximal measurements. Multivariate analysis showed that the majority of the variation in stiffness was explained by variation in I. Branching pattern, fin ray density and I are the largest factors contributing to interspecific differences in fin stiffness. Variation in I, E, segmentation, and branching patterns combine to produce the overall stiffness field of a pectoral fin surface, contributing to its dynamic shape during locomotion.

130.6 AKANYETI, O*; YANAGITSURU, YR; STEWART, WJ; LAUDER, GV; LIAO, JC; University of Florida, Eastern Florida State College, Harvard University; *otar@whitney.ufl.edu*

Undulatory fishes increase tail beat amplitude during acceleration for high propulsive efficiency

The ability to accelerate quickly is essential for survival, as it underlies critical behaviours such as prey capture and predator evasion. Far from being an extension of steady swimming, whereby the tailbeat (tb) amplitude is approximately constant at 0.2 body length (L) and swimming speed is modulated primarily by increasing tb frequency, we argue here that acceleration is a distinct type of locomotion that has distinct optimization parameters. We suggest that this phenomenon is generalized to all fishes, given that we observed similar acceleration kinematics in more than 50 species of fishes with vastly different body shapes, swimming modes and ecological habitats. We found during acceleration tb amplitude is 25% higher than during steady swimming. To uncover how elevated tb amplitude relates to thrust production and propulsive efficiency, we used a combination of flow visualization experiments on live fish and experiments with soft-bodied robotic models. Results from particle image velocimetry show that rainbow trout (*Oncorhynchus mykiss*, $L = 22.4 \pm 2.0$ cm) can reach a maximum acceleration rate of 15 $L\ s^{-2}$ from initial swimming speed of 3 $L\ s^{-1}$ by generating thrust 4 times higher than that required to maintain the initial speed. To do this, fish entrain more fluid around the body anterior to the tail, and exploit these fluids with synchronized tail movements to enhance vortex shedding by 100%. Complementary experiments with a 3D-printed robotic fish model show that increasing tb amplitude during acceleration can increase propulsive efficiency up to 50%. Our results reveal that optimum tb amplitude values for acceleration and steady swimming do not overlap, and fishes adopt acceleration kinematics that are tuned for high propulsive efficiency.

P3.158 ALBA, JC*; BERGSTROM, CA; TAMONE, SL; University of Alaska, Southeast; *jcalba@alaska.edu*

Investigating metabolic rates of estuarine groundfish in habitats of varying glacial effluence

Climate change is affecting the planet in numerous ways, including increased glacial effluence into marine waters. The rate of glacial melt is predicted to increase in the short term and eventually cease, which means that in the near future increasing volumes of cold fresh water will be released into estuaries. It is unknown whether these changes to estuarine habitat characteristics are affecting organisms and the overall ecosystem. This project will investigate impacts of climate change on fish health by comparing metabolic rates of an indicator species, Starry Flounder (*Platichthys stellatus*), among estuaries that vary in their influence by melting glaciers. We predict that organisms from estuaries with the highest glacial effluence will show reduced metabolism compared to individuals from estuaries of lower glacial effluence. *P. stellatus* individuals were collected from estuaries of varying glacial effluence in Southeast Alaska. After a 24-hour fasting period under common conditions in a flow-through seawater system, each specimen's rate of oxygen utilization was measured with a Loligo vertical respirometry chamber using a Witrox 4 oxygen meter. Oxygen utilization was controlled for body mass, and will be compared among fish from the different estuaries. The implications of this research will allow us to determine if melting glaciers are having a detectable effect on fish metabolism and health, contributing to the mounting body of evidence of how climate change is impacting marine organisms

43.1 ALBERT, J.S.*; SCHOOLMASTER, D.R.; TAGLIACOLLO, V.A.; DUKE-SYLVESTER, S.M.; University of Louisiana at Lafayette, US Geological Survey, Universidade Federal do Tocantins; *jalbert@louisiana.edu*

Barrier Displacement on a Neutral Landscape: Towards a Theory of Continental Biogeography

Five broad regularities of biogeography and biodiversity are observed in many taxa with continental distributions: 1, power function-like species-area relationships; 2, log-normal distribution of species geographic range sizes; 3, mid-domain effects with more species towards the geographic center, and more early-branching, species-poor clades towards the geographic periphery; 4, exponential net diversification with log-linear accumulation of lineages through time; and 5, power function-like relationships between species-richness and cladal-diversity, where most clades are species-poor and few clades are species-rich. However, current theory does not provide a robust mechanistic framework to connect these seemingly disparate patterns. Here we present SEAMLESS - Spatially-Explicit Area Model of Landscape Evolution by SimulationS - that generates clade diversification by moving geographic barriers on a continuous, neutral landscape. SEAMLESS models the effects of barrier displacement on all three terms of macroevolutionary diversification: dispersal, speciation, and extinction. Barrier displacement merges adjacent areas allowing dispersal and larger geographic ranges, separates adjacent areas resulting in vicariant speciation and smaller geographic ranges, and subdivides areas resulting in extinction below a minimum species persistence threshold. SEAMLESS shows how dispersal is required to avoid clade-wide extinction, demonstrates that ancestral range size does not predict species richness, and provides a unified explanation for the five commonly observed biogeographic and phylogenetic patterns described above. SEAMLESS contributes to a theory of continental biogeography by modeling the macroevolutionary consequences of landscape evolution processes.

S10.9 ALBERTIN, C.B.*; RAGSDALE, C.W.; University of Chicago; *carrie.albertin@gmail.com*

Conservation, convergence, and novelty in Octopus bimaculoides embryogenesis

Cephalopods have a highly derived body plan and a suite of innovations with no obvious correlates in other animals. More striking in many ways than the disparities in the adult body plan is early development in cephalopods, which lacks any trace of the spiral cleavage program characteristic of non-cephalopod molluscs and other spiralians. Instead, cephalopod embryos undergo bilateral, meroblastic cleavage on top of a large yolk, morphologically resembling early embryogenesis in fish and constituting yet another example of convergence between these two distantly related groups. To shed light on the gene networks important in this highly derived developmental program, we sequenced and analyzed transcriptomes from five stages spanning embryogenesis in the California two-spot octopus, *Octopus bimaculoides*. Genome analysis has shown that the core developmental gene repertoire of the octopus is broadly similar to that found in typical invertebrate bilaterians (Albertin et al. 2015). We detect transcripts for these developmental transcription factors and signaling ligands primarily during the middle stages that coincide with the emergence of the body plan, but not before. Bioinformatics-based differential expression analysis identified suites of genes that show dynamic changes, including stage-specific expression profiles. Notably, many of the differentially expressed genes in the early transcriptomes are not found in the genomes of other sequenced animals. These results indicate that the fish-like early stages of cephalopod development deploy cephalopod-specific genes, and suggest a major role for taxonomically restricted genes in the evolution of cephalopod developmental mechanisms.

13.1 ALBERTSON, RC*; KAWASAKI, K; POWDER, KE; Univ. of Massachusetts, Amherst, Clemson Univ.; *albertson@bio.umass.edu*

Genetic and developmental basis for scale shape variation in Lake Malawi cichlids

Epidermal appendages (EAs) are a defining characteristic of vertebrates, and their evolutionary success may be credited, in part, to the developmental elaboration of these structures. One common EA is the scales of fish. While we have a solid grasp of how scales develop, as well as the developmental cues that differentiate scales from other EAs, little is known about the genetic mechanisms that underlie variation in scale shape. Such variation is likely to be important across species adapted to different habitats, as well as within an animal where serially homologous scales may be under different selective pressures at different points on the body (e.g., streamlining anteriorly, protective posteriorly). Using an F2 mapping cross between cichlid species with different scale phenotypes, we identified >40 quantitative trait loci (QTL) for numerous measurements of scales from distinct positions on the fish. We found that while certain regions of the genome regulate variation in multiple scales, most are specific to scales at distinct points along the anterior-posterior axis of the body, which suggests a degree of genetic modularity in scale development. We also identified a QTL for scale shape disparity, which suggests that shape variation across serially homologous scales has a tractable genetic component. Finally, using population genomics, we screened QTL intervals for candidate genes, and identify many previously implicated in EA development, including components of Fgf, TGF-beta, and Ephrin signaling pathways. These data suggest that the same genes involved in scale development might also mediate scale shape.

P1.42 ALI, S*; ANDERSON, RC; Florida Atlantic Univ.; *sabahali2013@fau.edu*
Song as an Aggressive Signal in the Bachman's Sparrow, Peucaea aestivalis
We conducted a field experiment to study the male-male aggressive function of song and singing behavior in the Bachman's sparrow. An aggressive signal is one that is 1) associated with an aggressive context, 2) predicts attack or escalation towards attack, and 3) is responded to by receivers appropriately, i.e., with aggressive escalation or retreat. We are testing these predictions for three types of song produced by territorial male Bachman's sparrows in response to a threat by a rival male: 'primary song,' low amplitude 'whisper song,' and 'excited song'. During the breeding season (May-June) we performed simulated territorial intrusions (STIs), using song playback and a model of a male Bachman's sparrow, on the territories of 30 males at Johnathan Dickinson State Park in south Florida. We are quantifying the subject males' vocal and other behavioral responses with the aim of determining which vocal behaviors, if any, are reliable threat signals, and if particular sequences of signals predict escalation versus de-escalation. We are analyzing movement, proximity and attack behaviors to quantify each male's aggressiveness, and will relate aggressiveness to song type use and other aspects of singing behavior (song rate, song type switching rate). Our results will contribute to a better understanding of the social behavior and communication system of this enigmatic species.

87.3 ALLEN, PE*; MILLER, CW; University of Florida, Gainesville; *pabloallen@ufl.edu*
Diet-by-temperature interactions on a sexually selected trait and sexual dimorphism
Sexual dimorphism is often the result of condition-dependent expression of sexually selected traits, like animal weapons. Most commonly, larger males that developed under nutritionally rich conditions grow disproportionately bigger weapons than smaller individuals that developed under poor nutritional conditions. Meanwhile female homologous traits generally do not experience this developmental plasticity in such a way. But the degree of sexual dimorphism has also been attributed to abiotic factors, like temperature. And even though the connection between condition-dependence and sexual dimorphism is obvious, this connection has been ignored until recently. Here, we investigated the relationship between condition-dependence and sexual dimorphism using two ecologically relevant environmental factors, natural diet and temperature. We used the leaf-footed cactus bug *Narnia femorata*; the males of this sexually dimorphic species possess enlarge hind legs used in male-male contests. As expected diet had a major effect on all traits, but it was disproportionately stronger on hind leg traits (sexually selected weapons). Temperature had a significant effect on some traits, including hind leg traits. Furthermore, diet and temperature interacted to create treatment-specific differences between male and female phenotypes. This study highlights how natural variation of environmental factors can interact and cause the differential expression of morphological traits across environments.

82.1 ALLISON, WT; Univ. of Alberta, Edmonton, Canada; *ted.allison@ualberta.ca*
Regressive evolution of the hagfish visual system: blind but hopeful monsters
We study the Pacific Hagfish in an evo-devo framework, with special attention to the first appearance of the vertebrate eye over evolutionary time. Other cyclostomes (lampreys) and all jawed vertebrates share the familiar camera-style eye. The last common ancestor of lamprey and vertebrates also had a photoreceptive pineal gland. Thus the Hagfish, oft-reported to lack a pineal, eyes and vision, are positioned perfectly to understand the appearance of the vertebrate eye over evolutionary time. The eyes of adult hagfish are quite small and buried under a layer of epidermis, leading credible sources to suggest hagfish lack vision altogether and their eyes are pineal-like in several characters. Here we revisit the rarely-examined Pacific Hagfish (Eptatretus stoutii), with special attention to the smallest (≈youngest) individuals we can acquire, and applying contemporary histology methods to reveal novel compelling arguments that hagfish possess almost all features of a vertebrate eye; this codifies hagfish eyes as functional, though degenerating during ontogeny. Three independent opsin antibodies all reveal robust photoreceptors at the outer nuclear layer and indistinguishable from vertebrates. Importantly, young hagfish retinas have three recognizable nuclear layers separated by synapses as detected by multiple stains and antibodies. Thus, several data sets all independently demonstrate that young hagfish have eyes that are not pineal-like, but have organization at the tissue- and molecular-level shared with lampreys and all jawed vertebrates. The data form a new baseline for interpreting evolution of rods from cones. In sum, the retina of Pacific Hagfish degenerates with ontogeny and adult tissues have been mis-interpreted to implicate that the eyes of hagfish never develop and never evolved; our data dramatically revise our understanding of the early vertebrate eye evolution.

P3.64 ALTO, SI*; STROTHER, JA; Oregon State University; *altos@oregonstate.edu*
Behavioral responses of zebrafish larvae to respiratory cues
Control of the ventilatory and cardiovascular systems is a vital physiological process in vertebrates. Several studies have shown that most fishes are able to detect gas concentrations in both the environment and the blood, and that they respond with changes in ventilatory rate, heart rate, blood flow distribution, and swimming patterns. However, relatively little is known about the respiratory physiology and control of respiration in larval fishes. We examined this question by recording the behavioral responses of zebrafish larvae to a range of respiratory cues, including low environmental oxygen and high environmental carbon dioxide. The behavioral responses were recorded by imaging the animal from two orthogonal perspectives, and performing automated reconstruction of the trajectory and midline kinematics of the animal. Numerous metrics were calculated from this dataset, including percent time swimming, swimming speed, position in the water column, and tail beat frequency. Our results suggest that different respiratory cues in the environment have characteristic effects on the behavior of the larvae.

137.3 AMBARDAR, M*; GRINDSTAFF, JL; MEDHAVI, Ambard; Oklahoma State University; *medhavi.a@gmail.com*

Do gonadotropin-releasing hormone-induced testosterone levels predict reproductive success in eastern bluebirds (Sialia sialis)?

Hormones, such as testosterone, are integral in mediating physiological processes and behaviors that facilitate reproduction. Thus, an understanding of the relationships between hormones and reproductive success may provide an avenue for understanding the evolution of hormonal profiles. Some previous studies have established direct links between reproductive success and testosterone levels by experimentally manipulating testosterone levels and investigating the impacts on reproduction. However, measures of individual variation in testosterone levels are also needed as they are necessary to assess how selection might act on hormone levels. In addition, testosterone manipulations may elevate testosterone levels beyond an individual's natural maximum capacity. Gonadotropin-releasing hormone (GnRH) challenges provide a method of measuring the natural maximum testosterone levels that an individual can produce. Recent work in dark-eyed juncos (*Junco hyemalis*) has demonstrated that males with higher testosterone produced in response to GnRH had higher reproductive success. Relatively fewer studies have investigated relationships between reproductive success and testosterone levels in females, but to understand how hormones evolve in a species, it is important to study both sexes. We conducted GnRH challenges on male and female eastern bluebirds (*Sialia sialis*), and related GnRH-induced testosterone levels to clutch size, number of offspring fledged, and offspring mass. Unlike the previous study on juncos, we did not find a positive relationship between measures of reproductive success and GnRH-induced testosterone levels in male and female bluebirds. Our findings suggest that the relationships between reproductive success and testosterone in both sexes are complex and may vary among species.

P2.158 AMES, AM*; MURRAY, JA; Friday Harbor Labs, University of Washington, California State University, East Bay; *aames@uw.edu*

Ciliary-driven currents may enhance olfactory sampling in nudibranch gastropods

Chemosensation is a key component of navigation and communication for aquatic invertebrates. The posterior tentacles of nudibranchs are called rhinophores and are their primary olfactory organs. We videoed and measured active water currents driven by cilia around the clavus of rhinophores using dyes and neutrally-buoyant glass beads to observe speed and patterns of flow. The speed of particle flow toward the rhinophore averaged between 0.1 and 1.0 mm/s across five species, and particles were apparently pulled in viscous laminar flow toward the rhinophore from up to 3-5 mm away. For the lamellate rhinophores found in dorid species, fluid is split into medial and lateral lamellae at the midline of each rhinophore and moved anterior to posterior through the lamellae. These rhinophores can rotate around their vertical axis to pull in water from the left or right. In other dendronotid species, fluid is pulled downward into the cup-shaped clavus of the vertically-oriented rhinophore and released in all directions at the base of the clavus before the stalk. In a burrowing arminid fluid moves distally to proximally parallel to the ridges of the conical rhinophore. Scanning electron microscopy showed densely-ciliated areas on the unexposed surfaces of the rhinophores which facilitates fluid movement through the leaflets of the clavus. Exposed surfaces had small patches of presumably-sensory cilia as found on all skin. We hypothesize that these currents minimize the boundary layer thickness and thus decrease the response latency of olfactory receptors to changes in odor density, and also increase the volume of water sampled per time. Some species show little or no current flow and a comparative study will help us determine the adaptive function of sniffing.

P2.179 AMMAGARAHALLI, B*; LAYNE, JE; ROLLMANN, SM; Univ. of Cincinnati; *ammagaba@uc.edu*

Host plant shift alters peripheral olfactory perception and divergence of Drosophila mojavensis populations

Ecological speciation is driven by divergent natural selection among populations that experience different local habitats. For herbivorous insects, such differences can be differences in host plant availability, and divergent selection can lead to reproductive barriers between populations. *Drosophila mojavensis* is a cactophillic fly composed of four populations, each specializing on a different cactus. The flies identify the appropriate cactus host by the unique odorants they emit, and this creates selection pressure on the tuning and sensitivity of olfactory senses. Thus, *D. mojavensis* is an ideal species in which to study the proximate mechanisms of reproductive isolation resulting from differences in local habitat. Here, we explore the evidence for ecological speciation via a host shift by examining peripheral olfactory systems of *D. mojavensis*, with the goal of understanding mechanisms underlying their host specialization. Response profiles of olfactory receptor neurons to host cactus odorants are found to be different between populations and are sex specific. Our findings suggest a host shift alters peripheral olfactory perception and may eventually lead to divergence between populations.

39.1 AMUNUGAMA, K; JIAO, L; OLBRICHT, G.R; WALKER, C; HUANG, Y-W; NAM, P; HOU, C*; Missouri University of Science and Technology; *houch@mst.edu*

Cellular oxidative damage is more sensitive to biosynthetic rate than to metabolic rate: A test of the theoretical model on hornworms (Manduca sexta larvae)

We develop a theoretical model from an energetic viewpoint for unraveling the entangled effects of metabolic and biosynthetic rates on oxidative cellular damage accumulation during animal's growth, and test the model by experiments in hornworms. The theoretical consideration suggests that most of the cellular damages caused by the oxidative metabolism can be repaired by the efficient maintenance mechanisms, if the energy required by repair is unlimited. However, during growth a considerable amount of energy is allocated to the biosynthesis, which entails tradeoffs with the requirements of repair. Thus, the model predicts that cellular damage is more influenced by the biosynthetic rate than the metabolic rate. To test the prediction, we induced broad variations in metabolic and biosynthetic rates in hornworms, and assayed the lipid peroxidation and protein carbonyl. We found that the increase in the cellular damage was mainly caused by the increase in biosynthetic rate, and the variations in metabolic rate had negligible effect. The oxidative stress hypothesis of aging suggests that high metabolism leads to high cellular damage and short lifespan. However, some empirical studies showed that varying biosynthetic rate, rather than metabolic rate, changes animal's lifespan. The conflicts between the empirical evidence and the hypothesis are reconciled by this study.

P2.277 ANDERSON, JM*; DIMARIO, PJ; HAND, SC; Louisiana State University; *shand@lsu.edu*

Expression of LEA Proteins in Embryos of Drosophila melanogaster and Influence on Desiccation Tolerance

The genus *Drosophila* contains over 1,500 species that inhabit diverse habitats including deserts, tropical rainforests, and alpine zones. Despite these varied habitats no species of *Drosophila* has been shown to tolerate major desiccation, and instead mechanisms to resist water loss have evolved. In animals, expression of late embryogenesis abundant proteins (LEA) is tightly correlated to life cycle stages that are desiccation tolerant. LEA proteins prevent protein aggregation and stabilize membranes during desiccation. We have created *D. melanogaster* fly lines that express transgenic LEA proteins (AfrLEA2 or AfrLEA3m), which are naturally accumulated in desiccation tolerant cysts of *Artemia franciscana*. Western blots confirmed that AfrLEA proteins are expressed in our transgenic lines of *D. melanogaster*. To investigate the impact of accumulation of LEA proteins on desiccation tolerance, we dried 18-20 h embryos of *D. melanogaster* for 4 h at 55% humidity and 22°C. This drying regime removed 80% of embryo water. Embryos then were rehydrated and scored for eclosion 72 and 120 h later. For individuals expressing AfrLEA2 or AfrLEA3m, the number of eclosed embryos 72 h post-rehydration was modestly lower than that observed for non-dried embryos [90.2 ± 13%, ± SD (n=3) and 88.0 ±1.1% (n=3) of non-dried embryos, respectively]. Eclosion of dried control embryos (without either LEA protein) was significantly lower at 72 h post-rehydration compared to embryos expressing LEA proteins [8.8 ± 8% (n=3) of non-dried embryos, one-way ANOVA, $p < 0.05$] and increased after 120 h of rehydration to 64.4 ± 44% (n=3). These data show that expression of AfrLEA proteins significantly reduce recovery time after desiccation in *D. melanogaster* embryos. [Supported by NSF grant IOS-1457061/IOS-1456809]

29.8 ANDERSON, P*; HU, Y; NELSON-MANEY, N; Univ. of Illinois, Urbana-Champaign, Univ. of Rhode Island, Kingston, Univ. of Massachusetts, Amherst; *andersps@illinois.edu*

The odd couple: common patterns of mechanical sensitivity in sunfishes and mantis shrimp

Evolutionary biomechanics offers an opportunity to explore the evolution of disparate biological systems that share common underlying mechanics. Sunfish and mantis shrimp are united by having prey-capture mechanisms actuated by four-bar linkages. Sunfishes capture prey via their oral jaws that are mobilized in part by a linkage connecting the mandible and the operculum. Mantis shrimp subdue prey using a power-amplified raptorial appendage driven by a four-bar linkage. Previous work on the mantis shrimp linkage revealed an evolutionary pattern of "mechanical sensitivity" where the functional output of the linkage (kinematic transmission) was tightly correlated with evolutionary changes in some morphological components but not others. This differential sensitivity of mechanical outputs to changes in specific morphological components is potentially a common feature of linkage systems across biology. To explore this possibility, we compared evolutionary patterns in the four-bar systems of sunfishes and mantis shrimp to see if they would show similar evolutionary patterns. We built dynamic linkage models of both linkage systems and used phylogenetic generalized least squares regression (PGLS) to compare evolutionary shifts in linkage morphology and mechanical outputs derived from the models. We found that in both four-bar systems the kinematics are most sensitive to changes in the output link, while measures of overall displacement are sensitive to changes in the coupler link. Our study illustrates the power of comparative biomechanics, allowing us to compare the evolution of biological systems from different phyla based on common mechanical underpinnings.

107.5 ANDERSON, R*; NIEDERHAUSER, J; DUBOIS, A; NOWICKI, S; SEARCY, W; Florida Atlantic Univ., Univ. of Miami, Duke Univ., Univ. of Miami; *rindy1@gmail.com*

Are Song Sparrow 'Soft Songs' Adapted for Short-range Communication?

Low amplitude acoustic signals are often produced during social interactions at close range. In the song sparrow, 'soft songs' are a reliable threat signal produced during male-male aggressive interactions. A prominent explanation for low amplitude signals is the eavesdropping avoidance hypothesis (EAH), which posits that quiet signals reduce the costs associated with attracting eavesdroppers such as competitors or predators. If true, then other acoustic traits of quiet signals besides low amplitude should be adapted to decrease transmission. We tested this prediction in a field experiment by comparing the transmission properties of song sparrow 'broadcast' songs (normal amplitude), low amplitude 'crystallized' soft songs and low amplitude 'warbled' soft songs. We recorded all songs played at both broadcast amplitude (85 dB SPL) and low amplitude (65 dB SPL). In general, the three songs categories did not differ in transmission properties when played at the same amplitude, with the exception that at broadcast amplitude, both types of soft song had larger tail-to-signal ratios (poorer transmission) than broadcast song. However, warbled soft songs had a significantly greater signal-to-noise ratio (better transmission) compared to crystallized soft songs or broadcast songs, especially when all songs were played at low amplitude. Also, both types of soft song had lower blur ratio (better transmission) at low amplitude. In general, we find little support for the idea that soft songs are adapted to limit transmission range, and in fact, some results suggest the opposite.

51.2 ANDERSON, RA; ANDERSON, Roger; Western Washington University; *Roger.Anderson@wwu.edu*

Patterns of Climate-related Body Condition among Desert Lizards differing in Food Acquisition Modes

Three sympatric lizard species, all largely insectivorous, are syntopic in the northern Great Basin desert scrub, but they differ in their food acquisition modes and the primary prey they consume. The year-to-year variation in precipitation and temperatures, and the resulting prey availability are expected to affect the annual variation in daily food intake and body condition of each species. Based on prior research, the western whiptail lizard, *Aspidoscelis tigris*, as an intensive, wide forager was hypothesized to maintain a relatively uncompromised body condition and should have a high daily food intake even in years of relatively low arthropod availability. In contrast, body condition and feeding rate in the blunt-nose leopard lizard, *Gambelia wislizenii*, which is an ambusher, were expected to be more sensitive to climate variation and prey availability. The desert horned lizard *Phrynosoma platyrhinos*, a myrmecophilic trapline-forager which moves among ant colonies, also was expected to maintain feeding rate and body condition at an overall high level among years, given the abundance and diversity of ants on site. The consequence of the among year variation in body condition should be similarly varying in number of young recruited into the population the next year. Outcomes were largely as predicted, but more detailed temporal analyses of female energetics and hatchling survivorship would be revealing.

P2.139 ANDERSON , S.; CRUZ, P.; FOLKS, N.; JOHNSON, M.; LOUBRIEL, D.; NIEDZIALEK, O.; PEREZ, M.; TRAVIS, D.; GONZALEZ, V.; HRANITZ, J.; BARTHELL, J.*; University of Kansas, Montclair State University, University of Texas at El Paso, Dickinson College, University of Puerto Rico at Rio Piedras, Bard College, Boston University, Bloomsburg University, University of Central Oklahoma ; *jbarthell@uco.edu*

Mark-Recapture Studies of Pollinator Species on the Greek Island of Lesvos

We examined the degree of movement of carpenter bees (*Xylocopa* spp.) and a megachilid (leafcutting) bee species that visit chasteberry (*Vitex agnus-castus*) and Greek horehound (*Ballota acetabulosa*), respectively, on the Greek island of Lesvos. Individual bees were marked with enamel paint and color-coded in a manner that identified them with their respective origins of collection (flowering plants). After release, sampling collections were subsequently repeated over a comparable period of time. Rates of return were calculated for each plant-pollinator system as an estimate of fidelity by the pollinator species to specific plants. In the case of the chasteberry, white and blue morphs of the bushes of this species were specifically compared with one another to detect preference by carpenter bees to the different color morphs. However, return rates were too low to detect significant differences, although bees in the Greek horehound - megachilid system revealed evidence of fidelity to certain plant locations. Our results most likely reflect differences in foraging scale wherein the relatively large-bodied and strong-flying carpenter bees are able to more easily traverse the greater distances required to visit the widespread chasteberry bushes across the island; megachilid bees, perhaps due to range limitations imposed by flight capability, remained more consistent in re-visiting Greek horehound patches in the immediate vicinity of nesting females. These findings have implications for understanding the results of sister (pan trap) studies that demonstrate altitudinal bias among bee species.

P1.80 ANDERSON, S.*; TRAVIS, D.; HRANITZ, J.M.; GONZALEZ, V.H.; BARTHELL, J.F.; University of Kansas, Boston University, Bloomsburg University, University of Central Oklahoma, Edmond; *sarah.anderson989@gmail.com*

NECTAR DYNAMICS AND POPULATION BIOLOGY OF A SPECIALIST POLLINATOR OF FIELD BINDWEED

Spiral-horned bees *(Systropha curvicornis)* are native to Southern Europe and the Middle East and are solitary bee specialists on the field bindweed *(Convolvulus arvensis)* flower. *Systropha* are unique for their foraging behavior and male dimorphisms such as the spiraled antenna. Previous research reports aspects of male behavior, nesting biology and foraging behavior of *S. planidens*; however, little is known of the closely-related species, *S. curvicornis*. Our goals in this study were to describe the population and foraging behavior of *S. curvicornis*. We conducted three field experiments in two populations separated by less than 1 km in Çanakkale, Turkey. In Experiment 1, we measured nectar production, visitation on field bindweed from antithesis (~07:30) to flower closing (~13:30), and observed different levels of natural competition. In experiment 2, we determined the neighborhood area and population size of the two populations of *S. curvicornis* by conducting a mark-recapture study. In experiment 3, we studied the foraging behavior using a flight cage with a grid to estimate number of landings and distance traveled of individuals. The mark-recapture study showed a neighborhood range with less than a 30 meters radius and both populations to be fewer than 200 individuals. Although population dynamics were similar, *C. arvensis* at one site produced substantially more nectar than the other site. Variation in foraging behavior of individual *S. curvicornis* may be attributed to sex and presence or absence of competition from other pollinators.

40.2 ANDERSON, KM*; HELDT, KA; MUNGIA, P; RUSSELL, B; HARLEY, CDG; CONNELL, SD; University of British Columbia, University of Adelaide, Hong Kong University; *kat@zoology.ubc.ca*

Factorial manipulation of CO_2 and temperature on algal-herbivore pair demonstrates that changes in herbivore population size will drive species interaction not per capita effects.

Herbivores have the potential to maintain biodiversity and regulate primary productivity. Such interactions are potentially greatly affected by changes in individual metabolism and population size. Similarly, changes in primary producer palatability may mediate the top down pressure exerted by herbivore populations. There is reason to expect either or both of these processes to be affected by increases in ocean temperature and/or carbon dioxide associated with climate change. Using a mesocosm experiment spanning several generations of amphipod populations, we established that a strong interaction between elevated CO_2 and temperature drove a near doubling in overall herbivory. This increase in herbivory resulted from an increase in population size and biomass, despite evidence that *per capita* herbivore pressure will likely remain unchanged. It turns out that while temperature has a negative impact on *per capita* herbivore feeding rates and CO_2 a negative impact on algal palatability, when both algae and herbivores are simultaneously exposed to project the effects level out. In this way the impacts of climate change on population size swamp minimal changes in *per capita* level interaction strength.

P2.262 ANDRE, B*; SURMACZ, CA; HRANITZ, JM; CAKMAK, I; CAKMAK, S; Bloomsburg University, Bloomsburg, PA, Uludag University, Bursa, Turkey; *csurmacz@bloomu.edu*

Sublethal Stress Associated with Apiary Treaments for Varroa Mites

Honeybees (*Apis mellifera*) have experienced global declines linked to Colony Collapse Disorder (CCD). While CCD may be due to many factors, *Varroa* mites strongly influence hive health, directly as an ectoparasite and indirectly as a disease vector. Beekeepers control mites with acaracides, pesticides used to kill mites. We hypothesized that acaracides may cause sublethal stress in honeybees. The intracellular chaperone heat shock protein 70 (HSP70) has been shown to be an excellent biomarker for sublethal stress in bees. This research aimed to determine the levels of HSP70 in honeybees pre- and post-treatment with synthetic pesticides (coumaphos, an organophosphate and flumethrin, a pyrethroid) or natural (organic) pesticides formic acid, thymol mix, and oxalic acid). Pesticides were applied by standard beekeeping practices at manufacturers' recommended dosages for treatments of *Varroa* infestations. Bee samples were collected pre- and post-treatment. HSP70 levels were measured by ELISA in homogenized head capsules. Among the synthetic pesticides, coumaphos did not affect HSP70 levels while flumethrin decreased HSP70 levels, possibly associated with mite abatement. Among the natural pesticides, the thymol mix decreased HSP70 levels. The method of oxalic acid application affected sublethal stress levels; liquid oxalic acid treatment increased HSP70 levels, while steamed oxalic acid had no effect. Formic acid did not affect HSP70 levels. These findings suggest that the thymol mixture and flumethrin caused the least sublethal stress to bees and corroborates that bees are more sensitive to oxalic acid than formic acid, as natural acaracides.

P1.209 ANKHELYI, M.V.; WAINWRIGHT, D.K.*; LAUDER, G.V.; Harvard University; *dylan.wainwright@gmail.com*

Diversity of placoid scale structure in sharks: surface roughness and 3D morphology

Sharks have a multitude of defining evolutionary structures that distinguish them from other clades of fish. One such striking feature is their skin. The entire surface of shark skin is embedded with thousands of placoid scales or dermal denticles. While previous research has shown that denticles vary both around the body of a shark and among species, little has been done to quantify surface roughness and three-dimensional denticle structure. We investigated and quantified differences in scale shape and size on the skin of three individual smooth dogfish (*Mustelis canis*) using microCT scanning, gel-based surface profilometry, and histology. On each individual, we imaged between 8 and 20 distinct areas on the body and fins, and obtained selective comparative data from leopard, sharpnose, mako, gulper, and great white sharks. We generated 3D images of individual denticles and took measurements of denticle volume, surface area, and crown angle from the microCT scans. Surface profilometry was used to quantify metrology variables such as roughness, skew, kurtosis, and maximum and minimum height of surface features. These measurements confirmed that denticles on different body areas of smooth dogfish varied widely in size, shape, and spacing. Denticles near the snout are smooth and paver-like relative to denticles on the body. Body denticles have between one and three distinct ridges, a diamond-like surface shape, and a dorsoventral gradient in spacing and roughness. We noted considerable variation in denticle structure among regions on the pectoral, dorsal, and caudal fins, including a leading-to-trailing edge gradient in roughness. Surface roughness in smooth dogfish varied around the body from 10 to 70 microns, and all species studied showed a similar range of values.

P3.121 APANOVITCH, EA*; RIDDELL, EA; BIRSIC, G; SEARS, MW; Clemson University; *eapanov@clemson.edu*

Comparing three stress responses and their time dependencies using a state-space approach for a terrestrial salamander species

With global surface temperatures reaching new record highs year after year, rising temperatures are quickly becoming prominent stressors across the globe. Many organisms may be able to alter their physiologies to increase their probability of surviving these changes in temperature and associated fluctuations in humidity. Physiological stress responses are a set of mechanisms that may help to buffer organism from changing environments. Stress responses may also signal downstream effects that increase an organism's chance of survival. However, not all stress responses are beneficial, especially when stressors are prolonged or repeated. To investigate if temperature and humidity act as stressors among population of terrestrial salamanders from nature, we compare three stress metrics; leukocyte ratios, fecal corticosterone, and membrane bound corticosterone receptors. Leukocyte ratios and fecal corticosterone levels act over an intermediate time period (days), whereas, the regulation of membrane bound corticosterone receptors should occur over a more chronic timescale (weeks). Understanding the timescale over which these stress responses occur, in addition to what drives stress levels in our populations, will help us to build a mechanistic model that predicts future demographics from time dependent responses. Although both leukocyte ratios and fecal corticosterone show weak trends, the variability of each responses suggests additional stressors, we have yet to quantify, are important in this system. Therefore, interactions between abiotic factor such as temperature and humidity, and biotic factors such as behavior and competition may be driving *Plethodon* stress levels.

P3.180 APPLEBAUM, SL*; PAN, T-CF; MANAHAN, DT; University of Southern California; *sappleba@usc.edu*

Differential temperature sensitivity of respiration rate, protein synthesis, and ion transport in bivalve larvae

Temperature is a principal environmental regulator of biochemical and physiological rates. The study of biological temperature sensitivity, and especially that of metabolic rate, has been a central theme in comparative animal physiology. Extensive comparisons have been made among species, particularly between those inhabiting environments with contrasting temperature regimes. Less is known, however, about the relative temperature sensitivity of fundamental physiological processes within a species. Of particular interest is whether the Q_{10} value (fold-change in rate for a 10°C increase) for metabolic ATP-production is the same as those for ATP-consuming physiological and biochemical processes. If changes in rates of ATP-consuming processes with temperature are uncoupled from those that regulate ATP-production, then changes will occur in the allocation of ATP under temperature fluctuation. We measured acute Q_{10} values for several physiological and biochemical rates over a normal temperature range experienced by larvae of the Pacific oyster (*Crassostrea gigas*). Concurrent *in vivo* measurements were conducted for rates of oxygen consumption, protein synthesis, and ion transport by Na^+,K^+-ATPase. Experiments conducted with multiple cohorts of larvae showed that Q_{10} values for the rate of oxygen consumption differed substantially from those for protein synthesis and ion transport. These findings suggest that daily temperature fluctuations experienced by larvae in their natural habitat may exert regulatory control over energy allocation dynamics.

64.5 APRELEV, P*; KENNY, M; SOCHA, J; KORNEV, K; Clemson University, Virginia Tech; *paprele@clemson.edu*

Rheological behavior of insect hemolymph on macro-, micro-, and nano-scales.

Hemolymph in insects plays a vital role in processes that range in scale from macroscopic - such as primary wound healing - to microscopic - such as flowing through vessels to deliver nutrients - to nanoscopic - such as fending off bacteria and viruses. When studying insect biomechanics, it is therefore crucial to understand the rheological properties of hemolymph at different scales. From a rheological perspective, hemolymph is a suspension of adherent and non-adherent micron-sized hemocytes suspended in plasma. Even though at the macro-scale the suspension may behave as a single-phase liquid, it has been a long-standing challenge to measure its rheological properties at the micro- and nano-scales, where the effects of hemocytes can be significant. Here, we present the findings of a multi-scale rheological study of hemolymph using a combination of traditional and novel characterization techniques. To probe the macroscopic properties of hemolymph, we used a commercial cone-and-plate rheometer (Brookfield Engineering DV-II+ Pro) with temperature controlled using a circulating bath (model Lauda RE206. To probe the micro- and nano-rheology, we suspended magnetic micro- and nano-wires, respectively, in a droplet of hemolymph in a controlled inert atmosphere and performed magnetic rotational spectroscopy by rotating the probe with a rotating magnetic field. For both methods, we conducted trials in atmospheres of nitrogen (~99%) to prevent or lessen the effects of clotting induced by oxygen. Our findings show that as scale is reduced, the effect of hemocytes on rheology of hemolymph becomes increasingly dominant and drastically changes the mechanical response of the hemolymph.

P2.224 ARAOS, HL; BOGARDUS, RM; CHANG, Y; DONOHUE, KR; KROFT, KL; HATCH, KA*; HANLEY, D; Brigham Young University, Provo, UT, McCook Community College, NE, National University of Tainan, Taiwan, Long Island University, Brookville, NY; *kroft.kelley@gmail.com*

The Columbia Spotted Frog (Rana luteiventris): Another Species Persisting with Amphibian Chytrid Infection

The chytrid fungus, *Batrachochytrium dendrobatidis* (*Bd*), has been implicated in major declines in many populations, though responses to the fungus among populations and species are variable. The Columbia spotted frog (*Rana luteiventris*) exists in small, isolated populations in Utah and therefore, we sampled *R. luteiventris* for chytrid infection from sites in Utah's West Desert and Wasatch Range over two consecutive years (March-August 2004; May-June 2005). Using egg count data as indicative of effective population size, we ran a linear mixed-effects model to determine if *Bd* had an effect on population size at the sites over time. Presence or absence of *Bd* had a significant effect on egg mass numbers when taking site, time and macrosite into account, with infected sites in the Wasatch Range having fewer mean egg masses per unit area than uninfected sites in the West Desert. Since we did not find evidence of large-scale population declines over the study period, it is likely that populations in the Wasatch Range are persisting with *Bd*, though Bd may be affecting frog reproduction and/or survival.

30.5 ARBOUR, J.H.*; SANTANA, S.E.; University of Washington, University of Washington, Burke Museum; *jarbour@uw.edu*

Does evolutionary rate heterogeneity explain the uneven distribution of species diversity within Primates?

It is well known that species richness is unevenly distributed across the tree of life. Explanations for this pattern are widely debated, and include clade age, ecological limits, and changes in diversification rates. For most groups of mammals, it remains unclear which of these factors played a major role in shaping differences in species richness among clades. Using Primates as a focal group, we examine the role of clade age and evolutionary rate heterogeneity in the modern distribution of species diversity. We apply phylogenetic comparative methods to a recent phylogeny of Primates to identify discrete shifts in lineage diversification rate. We evaluate age and species richness relationships across Primate clades using Phylogenetic Generalized Least Squares (PGLS), and contrast patterns of species richness variation across the phylogeny with several models of lineage diversification. We find that Primate diversification has accelerated since its origin, with decreased extinction leading to a shift to even higher evolutionary rates in the most species-rich family (Cercopithecidae). Older primate clades tend to be more diverse, however a shift in evolutionary rate is necessary to adequately explain the imbalance in species diversity. Geographic distribution poorly explains divergence between macroevolutionary regimes, and other ecological factors may be more important. Unlike other mammalian orders, the global distribution of primate species diversity appears to have been strongly impacted by heterogeneity in evolutionary rates.

S5.8 ARCHIE, E.A.*; TUNG, J.; BLEKHMAN, R.; BARREIRO, L.; GRIENEISEN, L.; ALBERTS, S.C.; ALTMANN, J.; University of Notre Dame, Duke University, University of Minnesota, University of Montreal, Princeton University; *earchie@nd.edu*

Socially structured gut microbiomes in wild baboons

In humans and other social animals, social proximity between hosts can predict the composition of host-associated microbial communities (i.e. microbiomes). These effects are potentially important because inter-host differences in the composition of the microbiome can affect host physical functioning and health. To date, the mechanisms driving socially structured microbiomes and the functional consequence of these patterns remain largely unknown. Here we discuss our recent research on the well-studied Amboseli baboon population in Kenya. We find that socially structured gut microbiomes could be caused by direct and indirect transmission among group members and may affect the functional capacity of individual microbiomes. Specifically we find that: (1) each baboon social group harbors a distinct gut bacterial community; (2) baboons in larger social groups have more diverse gut bacterial communities than baboons in smaller groups; (3) the longer a male baboon has lived in a given social group, the more his gut microbiome comes to resemble those of his fellow group members; and (4) within social groups, grooming bonds predict microbiome similarity, even controlling for genetic relatedness or similar diets. Importantly, some of these social signatures extend to the genic content of the gut microbiome, suggesting that social context affects to the microbiome's functional capacities. We discuss these results in the context of the functional consequences of socially structured microbiomes and important future directions for this line of research.

124.3 AREND, LA*; BISWAS, D; STAMPER, SA; VAGVOLGYI, BP; FORTUNE, ES; COWAN, NJ; Bethel University, Johns Hopkins University, New Jersey Institute of Technology; *luke-arend@bethel.edu*

Active Sensing Movements are Modulated by the Strength of Sensory Feedback in Electric Fish

Animals routinely produce movements whose express purpose is to obtain sensory information, a process known as active sensing. To examine active sensing, we investigated Eigenmannia virescens as they performed a robust refuge tracking behavior using visual and electrosensory inputs. When tracking a refuge in the dark, the fish performs fore-aft oscillatory motions (i.e. active sensing) which shape spatiotemporal patterns of electrosensory feedback. Our hypothesis is that fish adapt these motions to maintain salient electrosensory feedback while tracking in the dark. A custom closed-loop experimental rig moved the refuge with gain proportional to the movements of the fish, suppressing or enhancing electrosensory feedback. There was a decrease in active sensing movements when electrosensory feedback was increased using a negative gain, and an increase in active sensing movements when sensory feedback was decreased using a positive gain. In this way, the fish alters the amplitude of its own motion in an inverse relation with experimentally imposed changes in feedback gain. Using this strategy, the fish maintains a fixed root-mean-squared error with respect to the refuge. This effect was also observed when controlling for the trajectory of the input stimulus, which was achieved using an open-loop playback experiment. These results indicate that fish adapt their active sensing motions in relation to the strength of sensory feedback.

P3.245 ARIAS, AA*; DOYLE, JB; VEGA, K; MEJIA, V; BRYAN, P; ALDANA, M; GONZALEZ, E; NORIEGA , M; MEMBRENO, NA; CASTRO, A; ELSEY, R; OWERKOWICZ, T; CSUSB, UCR, Louisiana Department of Wildlife and Fisheries; *004058404@coyote.csusb.edu*

Effects of Exogenous Acetazolamide on Growth and Calcium Flux in Alligator Embryos

For normal development and growth, archosaur embryos must rely on mobilisation of calcium from the calcareous eggshell. Dissolution of calcium depends on the enzyme carbonic anhydrase (CA) expressed in the chorioallantoic membrane (CAM). Earlier work on CA function in embryos has been limited to the domestic fowl (*Gallus gallus*), and shown that administration of the CA-inhibitor, acetazolamide (AZA), significantly decreased total calcium deposited into the yolk and embryo. We tested the effects of topical AZA administration on embryonic growth in the American alligator (*Alligator mississippiensis*), and compared its effects to that of physical eggshell removal from eggs. We used 6 clutches (190 eggs) and administered topical AZA (0, 150, 300 and 600 µg) in DMSO (20 µl) daily. AZA-treated eggs were compared to peeled eggs and sham-handled controls. Eggs were incubated at 30°C and treatment lasted 40 days. Like the eggshell-less group, AZA-treatment resulted in a significant decrease (20%) in alligator embryonic growth compared to the control group, and growth restriction varied in a dose-dependent manner. In contrast to the eggshell-less group, however, AZA-treated embryos had a significantly higher proportion of dry yolk mass and a greater fraction of yolk ash mineral. Eggshell thickness showed no significant difference between AZA and control groups. While AZA administration has deleterious effects on embryonic growth of crocodilians, it does not significantly reduce calcium transfer from the eggshell to the embryo and yolk, as observed in the domestic fowl. We conclude that AZA administration (at doses tested) does not effectively block calcium mobilisation in crocodilian eggs, and cannot be used in studies of calcium restriction on musculoskeletal development.

18.6 ARMBRUSTER, JW; STOUT, CC; HAYES, MM*; Auburn University; *malorie.hayes@auburn.edu*

An Empirical Test for Convergence Using African Barbs (Cypriniformes: Cyprinidae)

Evidence for convergence is often based on human perceptions of overall similarity. In order to overcome this bias, we use geometric morphometrics combined with an analysis of phylogenetic signal to determine if two sympatric species are similar in form due to due convergence or shared evolutionary history. The two species, *Enteromius aspilus* and *E. guirali*, are sympatric in the Dja River of Cameroon, are deep-bodied, are very similar in color, and appear to school together. The focal species co-occur with seven other species of *Enteromius* in the Dja River with the more fusiform shape seen in other small barbs across Africa. Mitochondrial data suggests *E. aspilus* and *E. guirali* are not sister taxa, and there is no phylogenetic signal when the phylogeny is overlaid on shape space. The convergence between the two is likely due to a variety of factors including predator avoidance and crypsis in open water, social mimicry to increase the benefit of the selfish herd effect, and increased protection of *E. aspilus* via Batesian mimicry of *E. guirali*, which has a protective dorsal spine.

77.7 ARMSTRONG, EJ*; STILLMAN, JH; TRESGUERRES, M; Univ. of California, Berkeley ; San Francisco State University, Univ. of California, San Diego; *armstrong@berkeley.edu*

Symbiont Photosynthesis in Giant Clams is Strongly Promoted by Host H^+-Transport.

Giant clams (genus *Tridacna*) are the largest living bivalves and, like reef-building corals, secrete massive calcitic skeletons and host symbiotic algae (zooxanthellae) from which they obtain a significant portion of their respiratory carbon supply. However, both processes (biomineralization and algal photosynthesis) require mechanisms for carbon concentration. In corals, vacuolar-type H^+-ATPases (VHAs) have been show to acidify the algal symbiosome, increasing symbiont photosynthesis. Because giant clams occupy similar habitats and perform similar biochemical functions to corals, we hypothesized that VHAs may play analogous roles in tridacnid tissues. We assayed for the presence, and investigated the potential functional roles of VHAs within various tissues of the small giant clam (*Tridacna maxima*). VHAs were present in all tissues assayed (gill, azooxanthellate byssal mantle, and algae-bearing siphonal mantle), but were ~ 3x more abundant in siphonal mantle where they were located in close proximity to algae-bearing tubules and sites of calcification. Further, VHA contribution to algal photosynthesis was substantial, with inhibition of VHAs reducing symbiont photosynthetic production by nearly 50% in vitro. Algal productivity in light-exposed mantle increased overall energy turn-over by ~ 100%, and therefore VHA activity likely confers strong ecological and energetic benefits to the host clam. These results confirm the presence of VHAs in tridacnid clams and suggest that, like in corals, they play an important functional role in algal energy generation, potentially sustaining massive growth and permitting the evolution of gigantism in the *Tridacna* lineage.

113.5 ARNOLD, PA*; CASSEY, P; WHITE, CR; The University of Queensland, QLD, Australia, The University of Adelaide, SA, Australia, Monash University, VIC, Australia; *pieter.arnold@uqconnect.edu.au*

Experimental evolution of dispersal-related traits in a model insect: morphological, physiological, and behavioural responses to spatial selection

Dispersal ability varies significantly among individuals, and much of this variation can be described by a suite of co-varying morphological, physiological, behavioural, and life-history traits (dispersal syndromes). While dispersal syndromes have been well-studied within and among populations, our understanding of the evolutionary trajectories of traits associated with dispersal under selection is limited. We used the red flour beetle (*Tribolium castaneum*) in a laboratory dispersal system to assess how spatial selection processes, for and against dispersal, affected dispersal-related traits. We measured body size, relative leg length, routine metabolic rate, and aspects of movement behaviour over seven generations of artificial selection. Here we will discuss our findings that body size rapidly diverged over seven generations, such that dispersers became smaller and non-dispersers became larger, and that dispersers had a lower metabolic rate. Small individuals were more energetically and biomechanically efficient at climbing, and were therefore the ones that dispersed more. The variance in dispersal rate and movement was maintained even under intensive selection for opposing dispersal behaviours. This indicates that individuals may maximise their fitness by producing offspring that exhibit a variety of dispersal behaviours; a hypothesis that is further supported by the lack of a trade-off between dispersal behaviour and reproductive success.

86.4 ARSTINGSTALL, K.A.*; STARK, A.Y.; YANOVIAK, S.P.; Univ. of Louisville; *katiearstingstall@gmail.com*
Adhesive Performance of Tropical Canopy Ants Varies with Substrate Temperature
The surface temperature of tree branches in the tropical rainforest canopy can reach up to 55°C. Ants and other small cursorial organisms must maintain adequate adhesive performance in this extreme microenvironment to forage effectively and prevent falling. Tarsal adhesion in ants is partly dependent upon liquid secretions (e.g., hydrocarbons) that vary in viscosity with temperature. Thus, we predicted that adhesive performance of canopy ants would decrease linearly with increasing surface temperature. We measured tarsal adhesion in 580 workers representing 11 species of canopy ants from Barro Colorado Island, Panama. We quantified shear loads by dragging ants individually across a glass plate heated to various temperatures spanning the range observed in the field (23°C to 55°C). Absolute loads ranged 0.1-5.6 g among species (up to 1,250 times their body mass). Adhesive performance showed three general trends: 1) a linear decrease with increasing temperature, 2) no relationship with temperature, and 3) nonlinear dynamics resembling classical thermal performance curves with a peak around 30°C. The mechanisms for these large interspecific differences remain to be determined, but likely reflect variation in tarsal pad morphology, and the volume or chemistry of the secreted fluid. Understanding such differences will reveal the diverse ways that ants cope with highly variable and often unpredictable thermal conditions in the forest canopy.

137.7 ASAMOAH, A; Kwame Nkrumah University of Science and Technology; *asamoah38@icloud.com*
What strategies do plants use in stress environments?
Plants survive all manner of stress environments to perform the functions they do in the biosphere. They rely on and develop all manner of strategies to enable them to do so repeatedly. Biochemical, cellular or morphological these strategies constitute lessons in themselves which when well understood could go a long way to benefit all manner of scientific and engineering disciplines. Thus, this talk aims to point out the array of strategies that plants use in stress environments and identify disciplines which such strategies could possibly be of interest to.

55.3 ASHTON, SE*; PARKER, MR; James Madison Univ.; *ashtonse@dukes.jmu.edu*
Sexual dimorphism in expression of steroid hormone receptors in garter snake skin
The production of many secondary sexual signals, including pheromones, is controlled by sex hormone action at the sites of signal synthesis. The red-garter snake (*Thamnophis sirtalis parietalis*) is an ideal vertebrate for studying the interaction between steroids and sexual signals: males exclusively rely on skin-based female pheromones during courtship and pheromone composition is augmented by treatment with sex steroids (e.g., males produce female pheromone if implanted with estrogen). But how do steroid hormones promote pheromone expression at the molecular level in snake skin? Feminizing effects of estrogens on sexual signals are known to result from activation of estrogen receptors α (ESR1) and/or β (ESR2), while masculinizing effects of androgens arise from androgen receptor (AR) activation. We hypothesized that ESR1, ESR2, and AR are expressed in garter snake skin but their expression is sex-dependent with female skin expressing higher levels of ESRs and males higher expression of AR. To test this, red-sided garter snakes (n=10 males, n=10 females) were collected in the spring mating season, and mRNAs from skin and control tissues (liver, gonad, kidney, intestine) were extracted and used to synthesize cDNAs. Primers were designed using the available *T. sirtalis* genome (NCBI) and tested in real-time PCR reactions. While all three receptor types were expressed in male and female skin, ESR1 was more highly expressed in female skin while AR showed greater expression in male skin. We thus attribute the feminizing effect of estrogen on pheromone phenotype in males to their lack of circulating estrogen and subsequently dormant ESRs. Further, activated AR may have an antagonistic role in pheromone expression since testosterone is a known inhibitor of pheromone production in male garter snakes.

P3.38 ASKIN, R*; MOOI, R; Colorado State University, California Academy of Sciences; *Rebeccaaskin10@gmail.com*
The Heart of the Problem: Phylogenetic Systematics of Burrowing Sea Urchins in the Genus Metalia (Echinoidea: Spatangoida)
The Spatangoida, commonly known as heart urchins, are among the most diverse sea urchin groups. Unlike other urchins, spatangoids have evolved secondary bilateral symmetry, with an anterior-posterior axis allowing them to move in one direction through the sands in which they live. The brissid genus *Metalia* Gray, 1855 has been characterized by its shield-shaped subanal fasciole, with extensions as anal fascioles on either side of the anal opening. However, morphology is insufficient to demonstrate monophyly of *Metalia*. Although *Metalia* includes some of the largest, most common heart urchins in the Indo-Pacific, the systematics are far from settled, with several new species to be described. We present the first partial phylogenetic analysis of the Brissidae using mitochondrial COI and nuclear 28S genes from *M. spatagus*, *M. sternalis*, *M. nobilis*, *M. dicrana*, and at least one new species ("big red"). Generic monophyly was tested using species of *Brissus*, *Brissalius*, *Anametalia*, *Meoma*, *Plagiobrissus*, *Eupatagus*, *Rhynobrissus*, and *Brissopsis*. For the most part, *Metalia* species grouped together, but there is an intriguing possibility that the aberrant *Plagiobrissus* is derived from within *Metalia*, as suggested by ontogenetic studies. The long-recognized species, *M. sternalis*, actually seems to consist of 2 species: a giant and a small form (the latter once thought to be juveniles of the former). We are working towards increased taxon sampling, and a careful integration of morphological evidence to describe new species, determine biogeographic patterns, and provide a clearer view of the evolutionary pathways that make this genus such an important element in coral reef ecosystems.

93.4 ASSIS, B.A.*; SWIERK, L.; LANGKILDE, T.; The Pennsylvania State University, Yale University; *brauliopsu@gmail.com*

Reproductive costs of male-typical ornamentation on female lizards may be offset by increased performance

The role of male ornamental traits is generally well understood within the context of sexual selection. However, females of some species display conspicuous ornamentation, the function of which is unclear. Some female fence lizards, *Sceloporus undulatus*, possess blue badges that are similar to, but less dramatic than, those displayed by males during courtship and dominance contests. Females bearing these badges face reproductive costs, including lower reproductive output and desirability as mates. These reproductive costs are difficult to reconcile with the maintenance of this trait and its high prevalence in some populations. To investigate the adaptive significance of this female trait, we compared performance and behavior of ornamented and unornamented female fence lizards and their offspring. Ornamented females achieved faster sprinting speeds, performed fewer agonistic displays, and had offspring that were more likely to flee from attacks by predatory invasive fire ants. These results suggest that ornamented females and their offspring may have advantages that could offset the reproductive costs associated with this trait. Future research will examine the mechanisms driving ornamentation, including testosterone, and the environmental conditions that may maintain intrasexual variation in the expression of this female ornament in wild populations (e.g., resource availability and operational sex ratio).

98.3 ASTLEY, H.C.*; MENDELSON, J.R.; GOLDMAN, D.I.; University of Akron, Zoo Atlanta, Georgia Institute of Technology; *hastley@uakron.edu*

Side-Impact Collision: Obstacle Negotiation Mechanics in Sidewinding Snakes

Snakes display several locomotor modes which allow them to overcome a wide range of terrain challenges. Sidewinding is a mode which allows snakes to move across yielding sand with high speed, low cost of transport, high endurance and maneuverability, and the ability to ascend sandy slopes. However, sidewinding locomotion also cuts a broad path through the environment, making it vulnerable to obstacles. To determine the extent to which obstacles disrupt sidewinding, if at all, we encouraged four sidewinder rattlesnakes (*Crotalus cerastes*) to cross a line of vertical pegs while recording overhead video. The method used to negotiate the peg line depended on the orientation of the peg relative to the anterior-most static region. If the peg contact occurred posterior to a static contact, the lifted moving portion of the snake was deformed around the peg and dragged through as the snake continued sidewinding (which we refer to as the "propagate through" behavior, 71% of trials), otherwise the snake would perform a "reversal" (23% of trials) (Astley et al, PNAS, 2015) to reorient or abandon sidewinding in favor of concertina locomotion (6%). Traversing the peg line typically resulted in a decrease in velocity, but the reduction in speed was much greater in concertina (mean +- s.d.: 64% +- 9% loss of speed) compared to reversals (50% +- 15% loss) and "propagate through" (46% +- 22% loss) responses. We hypothesize that the "propagate through" behavior depends upon compliance of the lifted segment due to unilateral muscle activity.

P2.213 ATWOOD, A.C.*; DAVIS, J.E.; CAUGHRON, J.J.; CAUGHRON, J.E.; Radford University; *aatwood4@radford.edu*

Antimicrobial Properties of Fungi from Microhabitats with Varying Moisture Levels Within the Madre de Dios Region of Peru

Rainforests cover approximately six percent of Earth's land surface, yet contain nearly 50 percent of all living organisms. The medicinal purposes of fungi found in these rainforests are extremely important to advancements in modern science. Throughout the rainforest, various microhabitats are present, each with its own set of diverse environmental factors. Within these microhabitats, the relationship between fungi and bacteria are of particular importance, because the two are in constant competition. Although all environmental factors contribute to the competition amongst bacteria and fungi, moisture plays a key role in this relationship because it strongly influences the growth rates of both bacteria and fungi. We set out to determine whether the environmental factors present within local microhabitats correlate with the antimicrobial properties of fungi, with a particular focus on local moisture differences. Twelve fungi were collected from three experimental sites (within 10 meters of a swamp, within 10 meters of a stream, and 50 meters away from both), after which Gram staining was used to conclude the classification of bacterial colonies that were locally extracted from the soil. Antimicrobial activity was determined using an adapted Kirby-Bauer method. After incubating overnight (≈ 16 hours) at an approximate temperature of 27°C, the diameter of the area of inhibition surrounding the fungal samples were measured, and those fungi with antimicrobial properties were identified. In this presentation, we will discuss the differences in locations from which fungi were collected, the relative antimicrobial activity of fungi from each location, the process of fungal identification, and the implications of our findings in relation to both medicine and fungal activity in situ.

P1.225 AUSTIN, CE*; STAPP, CS; GARCIA, A; GUNTHER, KL; ZULUETA, SA; BARRIOS, AS; HOESE, WJ; PAIG-TRAN, EM; California State University Fullerton; *cherise31993@gmail.com*

Regional Variance in the Material Properties of Blacktip Poacher (Xeneretmus latifrons) Scales: A Biomechanical Inspiration for Puncture-Resistant Armor

Agonid poachers are benthic, heavily armored fishes with modified, robust dorsal scales that protect against predation from above. We hypothesized the mechanical properties of blacktip poacher, *Xeneretmus latifrons*, dorsal scales are more mechanically reinforced compared to lateral and ventral scales. Blacktip poachers (n=28) were separated into two treatments: intact and partially descaled fish. Puncture tests were performed using an Instron 5942 on 1) scaled fish, 2) partially descaled fish, and 3) the scales that were removed. We measured three mechanical properties for each treatment group: fracture point (strength), Young's modulus (stiffness), and work of fracture (toughness). We calculated a mean ± S.D. for each treatment and compared the groups via ANOVA with post-hoc Tukey tests. Individual scales were 29% stronger than intact fish and 779% stronger than skin. Scales were 27% and 524% stiffer than scaled fish and skin, respectively, and 26% tougher than skin. Scales differed in strength, stiffness, and toughness between the dorsal, lateral, and ventral surfaces of the fish. Dorsal scales were significantly stronger (9.1MPa ± 5.6) than both lateral (4.8MPa ± 3.9; p=0.005) and ventral scales (5.7MPa ± 6.9; p=0.019). Isolated dorsal scales were significantly stiffer (10.4MPa ± 8.8) than lateral (5.9MPa ± 4.9; p=0.011) and ventral scales (5.3MPa ± 3.8; p=0.0009). Blacktip poacher scales are 1.5 times stiffer than bovid horn (keratin), and more than 5 times tougher than tooth enamel. Poacher scales are strong, stiff, and tough biological features that may provide biomimetic inspiration for future synthetic materials, such as puncture-resistant body armor.

P2.107 AUSTIN, SH*; LANG, A; MACMANES, M; CALISI, RM; Univ. of California, Davis, Univ. of New Hampshire; *suzannehaustin@gmail.com*

The hypothalamic-pituitary-gonadal transcriptome of the rock dove, and its response to stress

We investigated the effects of 30 minutes of restraint stress on the hypothalamic-pituitary-gonadal (i.e. reproductive) axis of rock doves (*Columba livia*) using high-throughput sequencing technology. We constructed an annotated de novo transcriptome assembly of the hypothalamus, pituitary, and gonadal tissues of both male and female doves. Using RNAseq, we characterized patterns of expression for each tissue and report differentially expressed genes and gene networks between groups and sexes. We also assessed the relationship between circulating corticosterone concentrations and differential transcriptome expression in response to restraint stress. These data offer a foundation on which future hypothesis-driven approaches and examinations of bidirectional interactions between genes and the stress response can occur.

33.2 AWBREY, JD*; KRUG, PJ; University of Louisiana, Lafayette, California State University, Los Angeles; *jawbrey@louisiana.edu*

Delimiting Cryptic Sea Slugs with Novel Integrative Methods

Cryptic species that are morphologically similar to named taxa pose pervasive taxonomic challenges in soft-bodied marine invertebrates. Molecular species delimitation methods can be used to discover taxonomically new species; however, morphology can be more informative than DNA in cases of cryptic species, because morphology can evolve faster than DNA sequences. A recent species delimitation method (iBPP) jointly analyzes molecular and morphological data to account for these processes. I applied this method to host-specialized sea slugs that have been suggested as biocontrol vectors for invasive algae: the genera, Oxynoe and Lobiger. I will present molecular and morphological evidence for two cryptic species in Oxynoe, and seven in Lobiger. Based on DNA sequence data from three genes per individual and five genes per nominal species, these 7 new species hypotheses were supported by at least one of three delimitation models: a single-gene barcode gap method, and two coalescent methods that vary in how evolutionary processes are modeled. As a final test of these species hypotheses, l used iBPP to combine six characters measured from the microscopic radular teeth, in an integrative approach for identifying and describing putative species.

11.2 AYERS, KD*; GUMM, JM; Stephen F. Austin State University; *krisdayers@hotmail.com*

Conservation genetics of endemic Cyprinodon rubrofluviatilis and invasive Cyprinodon variegatus

Hybridization is a natural process, however, human activities have contributed to an increase of hybrid species. In North America alone, 40% of fish species of conservation concern have been impacted by hybridization and introgression. Of eminent concern is the hybridization of native species with introduced or invasive species. Samples collected from the Brazos River from 2006 and 2012 display intermediate phenotypes between the invasive *Cyprinodon variegatus* and the native *Cyprinodon rubrofluviatilis*, suggesting that hybridization has occurred between these species. The extent of hybridization and introgression between two species can not be determined by morphological characters as cryptic hybrids, individuals that phenotypically look like one species yet possess alleles unique to the second species, may be present. Genetic analysis using microsatellite markers of five parental populations and four hybrid populations provides the resolution needed to identify hybrid individuals and determine the impact of *C. variegatus* in the Brazos River. Preliminary data show that alleles unique to *C. variegatus* are present in both putative hybrids collected from the Brazos River in 2013 and samples collected from Salt Fork of the Brazos River in 2014 and 2015 upstream from Possum Kingdom Reservoir. However, samples collected from the Wichita River and the Red River do not possess these unique *C. variegatus* alleles. This suggests that *C. variegatus* and cryptic hybrids may have been present further upstream than originally documented. Additional sampling and genetic analysis is needed to understand the full impact *C. variegatus* has had on populations of *C. rubrofluviatilis* and if conservation efforts are needed to protect the loss of *C. rubrofluviatilis* genetic integrity.

102.6 BABONIS, LS*; MARTINDALE, MQ; Univ. of Florida, Whitney Lab; *babonis@whitney.ufl.edu*

Novel cells and tissues lost: using ctenophores to model the evolution of diversity

Now considered to be the earliest diverging animal lineage, ctenophores (comb jellies) have become a valuable model for understanding the evolution of conserved metazoan features (e.g., neurons, photoreceptors). Conversely, ctenophores are unified by their possession of a truly unique, phylum-specific cell type (the colloblast), making these animals also an important model for the evolution of novelty. Colloblasts are secretory cells that line the tentacles of ctenophores; they release a sticky glue upon contact to facilitate capture of their planktonic prey. To understand the origin of colloblasts, we examined tentacle development in the model ctenophore *Mnemiopsis leidyi*. Tentacle development is complex in *M. leidyi*, with multiple lineages of embryonic micromeres contributing cells to the tentacles during early development. In the larval (cydippid) stage, the cells comprising the tentacles are generated constantly from a population of stem cells found in the base of the tentacle (the tentacle bulb). Treatment of cydippid larvae with a reversible inhibitor of cell proliferation (hydroxyurea) resulted in loss of tentacles in *M. leidyi*. One lineage of ctenophores (Beroidae) lacks tentacles completely, feeding exclusively on other ctenophores. The phylogenetic position of Beroidae suggests that tentacles (and therefore, colloblasts) were secondarily lost in this lineage. We compared cell dynamics and gene expression in *Beroe ovata* with wildtype and hydroxyurea-treated (tentacle-free) *M. leidyi*. Using this framework, we generate hypotheses about evolutionary gain and loss of cell types and the impact of these processes on speciation.

P2.134 BACHELLER, SK*; OROURKE, CF; RENN, SC; Reed College; *renns@reed.edu*

Gut Turnover: An Evolutionary Adaptation to Mouthbrooding in Astatotilapia burtoni

Female *Astatotilapia burtoni*, a species of mouthbrooding cichlid, voluntarily starve themselves for two weeks while their young develop. Little is known about the physiological mechanisms that have evolved to allow them to accomplish this. *A. burtoni* therefore represent an excellent animal model in which to study the mechanisms that integrate the regulation of feeding and reproduction. Brooders who are starving face different challenges than starving non-brooders; by comparing brooding and starved females, we aim to identify key evolutionary innovations that allow for mouthbrooding. In addition to the neural regulation of feeding, peripheral changes in physiology are also necessary to allow brooders to conserve energy. Gut cell turnover is an energetically expensive process that is expendable to brooders, who have substantially reduced gut usage for the duration of brooding, in contrast to involuntarily starved females who may resume gut usage at any time. By detecting cell proliferation and apoptosis in the intestines through immunohistochemistry, differences in cell turnover can be compared between starved, brooding, and fed female *A. burtoni*. Proliferating cells can be quantified using bromodeoxyuridine, a thymidine analog that incorporates into the DNA of new cells. Similarly, apoptosis can be quantified through the TUNEL assay, which labels the ends of fragmented DNA with a unique nucleotide analog. Gut turnover is an excellent starting point to study peripheral adaptations and changes that occur during the brooding period. Potentially a novel evolutionary adaptation for female *A. burtoni*, gut turnover can allow them to better endure the mouthbrooding process while limiting energetic costs. Further studies could examine cell turnover with higher resolution and throughout the brooding cycle.

95.7 BAGGE, LE*; JOHNSEN, S; Duke Univ.; *laura.bagge@duke.edu*

Anti-reflective invisibility cloak: monolayers of spheres reduce cuticle reflectance in hyperiid amphipods

Under the directional light field of the mesopelagic and the bioluminescent searchlights of potential predators, transparent animals may be revealed by reflections from their body surface. However, thin films of intermediate refractive index may reduce such reflections. We investigated the cuticle surfaces of seven species of hyperiids (Crustacea; Amphipoda) using scanning electron microscopy and found that their cuticles were covered with a monolayer of putative spherical bacteria (diameters ranging from 52 ± 7 nm S.D. on *Cystisoma* spp. to 320 ± 15 nm S.D. on *Phronima* spp.). Optical modeling demonstrated that these layers can reduce reflectance by over 100-fold, depending on wavelength, angle of the incident light, and thickness of the gradient layer. Additionally, we found that the refractive index of bacteria (1.44) is close to optimal to serve as a single coating anti-reflection scheme for a crustacean's chitinous cuticle in seawater. Although we only consider surface reflectance and not internal light scattering, the calculated Weber contrasts of a hyperiid cuticle with and without the spheres show that they decrease the reflectance of downwelling light enough to reduce the visibility of the cuticle. Preliminary sequencing identifies these spheres as *Prochlorococcus marinus* and a nanobacteria in the genus *Mycoplasma*. Bacteria and zooplankton in the open ocean have often been viewed as belonging to different, indirectly-linked food webs, but our study shows a direct association between nanobacteria and the cuticles of transparent planktonic crustaceans that may function to enhance crustacean camouflage.

50.5 BAGHERI, H*; VAJRALA, S; TADURU, V; WHITE, SX; LEE, D; PAZOUKI, A; EMADY, HN; MARVI, H; Arizona State University, California State University; *hbagheri@asu.edu*

Locomotion on Wet Granular Media

Granular media interaction poses a highly nonlinear behavior, creating difficulties when formulating analytical models for locomotion studies. This inadequate understanding of moving bodies interacting with complex natural substrates has hindered the development of terrestrial all-terrain robots. Even with the recent performance of experimental and computational studies of dry granular media, wet granular media remain largely unexplored. More specifically, this encompasses animal locomotion analysis and the physics of granular media at different saturation levels. Given that the presence of liquid in granular media alters its properties, it is advantageous to evaluate the locomotion of animals inhabiting semi-aquatic and tropical environments to learn more about effective locomotion strategies on such terrains. Lizards are versatile and highly agile animals. Therefore, this study will evaluate lizard species from such habitats that are known for their performance on wet granular media. An extensive locomotion study and morphology characterization will be performed on several species such as Dappled, Brown and Carolina Anole. A ground control system sized at 2x1 m^2 will be utilized for the granular locomotion experiments, where saturation level and inclination angle will be controlled. Simulations of the lizard interactions with wet granular media will also be performed in EDEM. This work aims to pave the way for developing bio-inspired robotic systems that can effectively traverse complex wet granular environments for scientific discovery, planetary exploration, or search-and-rescue missions.

128.7 BAHLMAN, J*; ALTSHULER, D; Univ. Bristish Columbia; *batman@zoology.ubc.ca*

How to overcome your physiology: decoupling wing and muscle motion in Zebra Finches

Birds modulate aerodynamic force in large part by varying wing velocity, and flapping velocity can be increased either through wingstroke amplitude or wingbeat frequency. Muscle physiology studies of zebra finches, a bird with a relatively high wingbeat frequency, predicts that the birds should not increase frequency because reducing the already brief muscle shortening period does not allow sufficient time for force development and/or generates excessive negative power. We tested this prediction by recording the wing kinematics and muscle strain from the *pectoralis major* of zebra finches while they flew carrying a range of weights (0 to 75% body mass). We found that the birds do increase wingbeat frequency to increase wing velocity, however they do it without decreasing the duration of muscle shortening. The pectoralis began shortening 6 to 10ms (14-26% of wingbeat) before the wing began moving downward, although the muscle began lengthening at the same time the wing began to elevate. This delay between muscle and wing extends the duration of shortening allowing more time for the muscle to develop force, while simultaneously reducing the wing downstroke duration. Across the weight treatments, the amount of delay increases, so that muscle shortening duration remains unchanged but the downstroke duration becomes smaller. With stroke amplitude remaining constant or increasing slightly, the resulting wing velocity is faster despite a constant muscle velocity. This decoupling between muscle and joint motion allows the bird to overcome the limitations of muscle physiology to enhance wing velocity. Such decoupling is characteristic of power amplification through an elastic element, similar to frog jumping. However, this phenomenon is more unusual because it occurs in a cyclic contraction and there is no obvious in-series tendon to store energy.

45.8 BAIOCCHI, TB*; CHOE, DH; DILLMAN, AR; Univ. of California, Riverside, Department of Biochemistry, Univ. of California, Riverside, Department of Entomology, Univ. of California, Riverside, Department of Nematology; *tbaio001@ucr.edu*
Entomopathogenic Nematode Host-Seeking Behavior and Attraction to Naïve and Infected Hosts
Entomopathogenic nematodes (EPNs) are insect parasites used as biological control agents. EPN infective juveniles (IJs)are free-living and employ host-seeking behaviors to locate suitable hosts for infection. The health of a potential host greatly impacts the success and reproductive potential of a newly-invading IJ. Infecting a naïve host incurs the risk of failure to overcome the immune response and the possibility that mates may not be encountered. An infected host includes several benefits - reduced host immunity and potential mates. Resources are depleted at late stages of infection, thus impeding the success of a newly invading IJ. We predicted that chemosensory information would enable IJs to determine the infection status of potential hosts. To study this, we examined the attraction of Steinernema species (S. carpocapsae, S. feltiae, S. glaseri, and S. riobrave) to naïve and infected hosts. We found that EPNs can differentiate between naïve and infected hosts, and that host attractiveness changes over time in a species-specific manner. We used gas chromatography, and mass spectrometry to identify odorants that may relay information about potential host health and infection status. Among the odorants we identified, we selected 2-buten-1-ol-3-methyl (prenol) and 3-hydroxy-2-butanone (acetoin) for further behavioral study. Both of these odorants were repulsive to S. glaseri and S. riobrave IJs in a dose-dependent manner. We also found that prenol elicits attraction behaviors from larval stage Drosophila melanogaster, suggesting that host-associated odors may have several roles, such as signaling avoidance and dispersal, and acting as an attraction signal to new hosts.

P1.244 BAKER, JA*; SHEN, Y; Clark Univ.; *jbaker@clarku.edu*
The Effect of Tannins on Swimming Performance of Threespine Stickleback
Tannins comprise a large class of natural compounds that are produced by plants for defensive purposes. A variety of forms accumulate in large quantities in plant tissue, after which they move throughout ecological systems when plants decay or are consumed by animals. In many aquatic systems, such as the boreal lakes inhabited by threespine stickleback, tannins may reach very high levels when plants decay each spring, and the presence of tannins in the aquatic environment is considered to be harmful to aquatic life. However, the specific effects of tannins on aquatic organisms, especially on fish, remain unclear. We examined the effect of tannins on aerobic capacity by estimating the prolonged swimming stamina of individual stickleback with a commonly used assay. Further, we framed our study within an evolutionary context by testing fish from each of three populations that we predicted would have become adapted to the natural tannin levels in their environments—ancestral marine stickleback; stickleback from a very low-tannin lake; and stickleback from a very high tannin lake. Embryos from wild-caught parents were raised for one year in laboratory tanks with negligible tannin levels. When fish reached 1 year of age, they were given the performance assay, after which they were held in water containing a moderate amount of tannins. Individually identifiable fish were tested every two days for the next two weeks. Performance was analyzed via a repeated measures design. Population, the repeated measure (days of exposure), and their interaction were all significant, with population and the interaction having substantial effect sizes. Results generally corresponded to expectations, with fish from the high-tannin lake performing best overall, and showing the least decline in performance with time.

6.6 BAKKES, DK*; SOLE, CL; MANSELL, MW; 1Gertrud Theiler Tick Museum, Parasites, Vectors and Vector-borne Diseases, Agricultural Research Council - Onderstepoort Veterinary Institute, Pretoria, 0110, South Africa, Department of Zoology and Entomology, University of Pretoria, Hatfield, 0083, South Africa; *BakkesD@arc.agric.za*
Evolutionary History of the Extant Silky Lacewings (Insecta: Neuroptera: Psychopsidae)
The Psychopsidae are a small family of Neuropterous insects that possess broad wings - creating a physical likeness to moths. Globally, they show a disjunct tripartite distribution (comprising of sub-Saharan Africa, south-east Asia and Australia) pointing to an ancient Gondwanan origin for the group. This study aims to explore the evolutionary history of the extant species by examining processes of phylogeny and historical biogeography. As such, the results inform the taxonomy of the group as well as contribute to the knowledge-base of speciation processes in a broad context. The methods include: 1) A revision of the Afrotropical taxa which is informed by integrated morphological and molecular evidence and 2) estimations of phylogeny and historical biogeography based on two mtDNA (COI,16S) and two nuclear DNA (18S, CAD) genes in combination with a 98-character morphological dataset. Additionally, an estimation of the phylogenetic niche is facilitated by distribution records for 19 (out of c. 26) extant species and global climate data. A new subfamily, and two new species are described, with synapomoric characters to serve for diagnosis. A reconstruction of the evolutionary history for the family is presented drawing upon evidence from genetics, morphology, inferred climatic niche, fossils, paleogeography and paleoclimate.

P2.205 BAKKES, DK; Gertrud Theiler Tick Museum, Parasites, Vectors and Vector-borne Diseases, Agricultural Research Council - Onderstepoort Veterinary Institute, Pretoria, 0110, South Africa; *BakkesD@arc.agric.za*
Gertrud Theiler Tick Museum - Standing on the Shoulders of Giants
The Gertrud Theiler Tick Museum was started with specimens collected by Gerald Bedford in 1912. Since that time, several prominent scientists have made contributions to the collection in both specimen depositions and scientific study. This has elevated the collection to stand as the largest to house African ticks globally, containing 55 type specimens and 375 identified species amongst more than 2 500 specimens. The value of museums in 21st century biology is a topic of important discussion in light of the biodiversity crisis and impending climate change. Moreover, museums may come of age once they acquire an adequate number of specimens and species that capture a considerable degree of natural variation. Study of this variation may be used to answer important questions regarding public health, agriculture, biodiversity and evolutionary processes. Of course, these are all underpinned by the relentless pursuit of the main function of museum collections - systematics. The Gertrud Theiler Tick Museum is poised to realise this vision, having come of age to represent the most complete collection of hard-earned African ticks. The raw data preserved in each specimen, comprising its species designation, morphology and collection data, in combination with modern methods of data capturing, analysis and dissemination will serve to elevate the Tick Museum further, toward a crucial position in a developing continent.

128.3 BALABAN, JP*; AZIZI, E; Univ. of California, Irvine;
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Elastic energy storage and thermal performance in fence lizards

Western fence lizards have a broad thermal performance range, achieving nearly the same maximal accelerations and velocities between 25 and 40° C, despite a significant decrease in maximal muscle power across this temperature range. Thermal breadth is not unique to these lizards, as it is a common feature in ectotherm performance. However, previous studies have found that lizard muscles are just powerful enough to attain peak acceleration performance at optimal temperatures, which should indicate a performance decline with decreasing temperature, and not the thermal robustness that has been observed. We hypothesize that the thermal breadth in lizards results from their use of elastic energy storage to amplify muscle power during the first few steps of acceleration. We tested this prediction using a combination of *in vitro* muscle experiments and kinematic analyses of lizard running. Peak accelerations required estimated muscle powers in excess of those measured *in vitro*, which indicates that lizards may be amplifying muscle power. Additionally, by measuring muscle fiber shortening and aponeurosis lengthening during isometric contractions of isolated ankle extensors, we found that hindlimb muscles can store a substantial amount of elastic energy, which may account for more than a third of the total work used during acceleration. To get more detailed view of the distribution of mechanical power in the hindlimb, we will use inverse dynamics to quantify joint-level power requirements during acceleration across temperatures. This work aims to understand the role of elastic elements in broadening thermal performance in locomoting ectotherms.

93.1 BALENGER, SL*; GRAB, K; ZUK, M; University of Mississippi, University of Minnesota-Twin Cities;
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Field Crickets Evolving in Silence Exhibit Increased Investment in Alternative Mating Tactics

Male field crickets typically produce a long distance calling song to attract females. In response to selective pressure by an acoustically orienting parasitoid fly, however, a wing mutation has arisen on the islands of Kauai and Oahu that renders >90% and 50% of male *Teleogryllus oceanicus* silent respectively. Such silent males avoid parasitization but are unable to attract females. We hypothesized that on Kauai pressure to locate females when calling males are rare has selected for males who are phonotactic towards conspecific male song because it increases their likelihood of intercepting females attracted to the calling male. Individuals from Kauai, Oahu, and Mangaia, a Cook Islands population without the silent mutation, either were or were not exposed to calling song during development. Satellite assays showed the males originating from Kauai and reared in silence moved closer to the speaker and spent more time engaged in satellite behavior than did their counterparts reared with calling song. Males from Oahu and Mangaia, however, showed no such effect of acoustic rearing environment on these behaviors. This suggests that there has been directional selection on Kauai for males that respond to reduced calling song in their environment with increased phonotaxis, thus compensating for their lack of song and increasing the chance of intercepting receptive females. We previously found a similar pattern when studying wandering behavior, suggesting that males from Kauai, but not Oahu and Mangaia, that increase their investment in alternative mating tactics when reared in the absence of conspecific song are under positive selection.

66.3 BALIGA, VB*; MEHTA, RS; Univ. of California, Santa Cruz;
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Size and shape in independent evolutions of cleaning in the Labridae and Gobiidae

Both body shape and size affect the locomotor behavior of organisms, but how these relate to other functional systems such as feeding requires an approach where independent origins of a trophic specialization can be examined. We use the evolution of cleaning behavior in clades within two marine fish families, Gobiidae and Labridae, to explore the extent to which specialization in this tropic strategy is associated with phenotypic evolution. While inference of how and when cleaning evolved in the Labridae has been established previously, we use similar methods to infer the temporal and topological trends of cleaning evolution in the Gobiidae. Through fitting evolutionary models, we explore the extent to which the evolution of cleaning has affected body size in these families, and find that certain smaller-bodied lineages within these families may have been historically "pre-adapted" to clean. We also infer a phylogeny for both families to generate a combined phylomorphospace of body shape using geometric morphometrics. Obligate cleaners exhibit significant morphological convergence in this phylomorphospace, while facultative and juvenile cleaner taxa show more varied patterns. Overall, the evolution of cleaning is associated with not just small body size but a reduction in body depth, elongation of the head, and a more terminal orientation of the mouth. These traits are presumed to enhance a cleaner's ability to remove ectoparasites that inhabit tightly-confined places such as the gills and oral cavity of their clientele.

76.6 BALOUN, DE*; GUGLIELMO, CG; Univ. of Western Ontario;
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Energetics of Migratory Bats during Stopover: A Test of the Torpor-Assisted Migration Hypothesis

The torpor-assisted migration hypothesis posits that migratory bats use torpor during daytime roosting to minimize refueling requirements and preserve fuel stores for nocturnal flights. Previous field studies indicate that bats regulate body temperature and time in torpor facultatively so that daily energy expenditure is independent of ambient roosting temperature. However, direct measurements of total roosting energy expenditure in relation to ambient and body temperature are lacking. Our objective was to measure full-day body composition change and energy expenditure of bats roosting at different temperatures to test the prediction of the torpor-assisted migration hypothesis that fat and energy use by bats is independent of ambient roosting temperature. We further tested whether torpor use is affected by migration season, sex and age. We predicted that bats would be more conservative with their fat stores during the spring than the fall, on account of the colder spring weather, especially in females that are gestating and facing imminent lactation. We predicted that juvenile bats would use more torpor than adults in the fall to ensure sufficient fat stores for migration. We captured silver-haired bats (*Lasionycteris noctivagans*) at Long Point Bird Observatory, Long Point, Ontario, Canada, a prominent stopover site for migrating birds and bats. We used quantitative magnetic resonance analysis to measure change in fat and lean mass and to calculate total energy expenditure during roosting at 10, 17, 25 degrees C for 12 hours (the length of a daytime stopover). Body temperature was continuously monitored with radio-transmitters. This study will test key predictions of the torpor-assisted migration hypothesis and further our understanding of energy management at stopovers for migratory bats species.

15.2 BARFIELD, SJ*; DAVIES, SW; MATZ, MV; Univ. of Texas, Austin, Univ. of North Carolina, Chapel Hill; *sbarfield@utexas.edu*

Genetic signatures of coral recolonization following extensive mortality by crown-of-thorns (Acanthaster planci) on Yap Island, Micronesia

Outbreaks of crown-of-thorns sea stars (Acanthaster planci) can cause localized extinction of corals, leading to extensive disruption of the coral reef community. However, many broadcast-spawning coral species are capable of rapid recolonization of disturbed sites, which can facilitate recovery. In 2010, a crown-of-thorns outbreak at the south tip of Yap Island led to the near complete local extinction of many Acroporid species. Samples of the table-top coral Acropora hyacinthus were collected prior to this outbreak in 2009. Our objective was to resample new A. hyacinthus coral individuals that have since recruited to this location in order to determine how local extinction and recovery has changed the genetic composition of the population. We utilized genome-wide markers (2b-RAD) to assess changes in genetic diversity and genetic differentiation between the former adult population and the new juvenile population. In order to assess genetic changes that were specifically associated with the local extinction/recolonization event, we also examined differences among adult and juvenile cohorts at two other sites unaffected by disturbance. Our results provide new insight into patterns of coral recruitment at disturbed and healthy reef sites and provide a test of the Sweepstake's hypothesis, which predicts that variability in the fecundity of marine broadcast-spawning species should result in reduced inter-cohort relatedness among juveniles.

P3.66 BARKAN, CL*; KELLEY, DB; ZORNIK, E; Columbia University, Reed College; *charlotte.barkan@gmail.com*

Evolution of vocal circuits: identifying neurons that underlie species-specific calls

The motor circuits of closely related species are well suited for examining proximate mechanisms that underlie divergent behaviors. Vocalization is a stereotyped motor behavior essential to successful courtship in many species. Males of extant species of the *Xenopus* genus produce a unique advertisement call to attract female mates of their own species. Two species, *X. laevis›* and *X. petersii*, diverged ~8.5 million years ago and produce calls consisting of two alternating trains of sound pulses: fast (~60 Hz pulses) and slow (~30 Hz) trill. Despite similar trill rates, their calls differ substantially in duration and period; *X. laevis* trills are longer and slower than those of *X. petersii*. In a fictively calling isolated brain preparation, in which nerve activity patterns resemble sound pulse patterns of advertisement calls, we use whole-cell recordings to identify premotor cells in the central pattern generators of both species. These cells typically produce spikes time-locked to nerve activity. In both species, most premotor neurons display a long-lasting depolarization (LLD) that coincides with each fictive fast trill. In each species, the LLD duration and period are strongly correlated with the duration and period of the fictive fast trill, respectively, and are significantly shorter in *X. petersii* than *X. laevis*. In the presence of tetrodotoxin, which blocks network activity, premotor neurons oscillate in response to NMDA in a species-specific manner. *X. laevis* neurons respond to increasing NMDA doses with a lengthening of the oscillation duration and period, while neuronal oscillations in *X. petersii* remain relatively short and rapid. We propose that unique cellular properties of these putatively homologous neuronal populations underlie vocal differences between *X. laevis and X. petersii.*

94.6 BARKER, RE*; SPONBERG, S; Georgia Institute of Technology; *bark.rach@gmail.com*

Just in time? Timing and rate encoding in the spike-resolved motor program of the hawk moth, Manduca sexta

Animals actively control locomotion through their motor program-the set of all neuromuscular activations controlling the limbs. In most vertebrates and slow moving animals, variations in the muscle activation amplitude, measured as spike rate encoding, are thought to be the dominating mechanisms of control. However, the role of activation timing has been implicated in the control of many invertebrates, even in the function of the main flight muscles of insects, which receive very few activating potentials. Both muscle activation time and muscle activation magnitude (spike number or rate) are now known to exhibit fluctuations associated with variations in behavior. Nonetheless, the relative importance of temporal vs. rate encoding across the whole of a motor program has remained elusive because most recordings only consider a few of the possible motor commands at any time. To meet this challenge we obtained a nearly complete spike-resolved motor program of the hawk moth, *Manduca sexta*. Examination of the muscle structure and anatomy as well as prior work on muscle function in hawk moths indicates that the primary neuromuscular determinants of wing motion during flight should arise from only 10 thoracic muscles. We took differential electromyogram recordings during open-loop tethered flight while the moth visually tracked a robotic flower stimulus. Using spike-sorting analysis, we identified spike-resolved firing from each muscle on a wing-stroke-to-wing-stroke basis. We isolated the effects of timing and rate relative to the motion of the flower. Precise control of timing may be an especially critical component of control when locomotor frequency increases and bandwidth constraints of neural systems are significant.

112.6 BARNARD, AA*; FINCKE, OM; MASLY, JP; University of Oklahoma; *alex.barnard@ou.edu*

How Do Females Evaluate Male Tactile Signals? Quantitative Variation in Female Sensory Structures and Implications for Species Recognition, Sexual Selection, and Speciation

Mate recognition can be important for maintaining reproductive isolation between closely-related species. Although much is known about animal mate recognition from studying male signaling traits and female preferences, it is more challenging to study the neurobiological basis of *how* females evaluate male signals. *Enallagma* damselflies provide a powerful model to understand the mechanistic basis of female mate selection. Females control whether mating occurs and it has been suggested that females evaluate tactile signals from the male grasping organs using sensory bristles (sensilla) on the thorax. These sensilla provide an external, quantifiable phenotype that can be used to test hypotheses about female mating decisions. *E. anna* and *E. carunculatum* hybridize in nature and hybrid males suffer reduced reproductive success. Because the species occur in both sympatry and allopatry, we can test the hypothesis that thoracic sensilla play a major role in species recognition and the evolution of reproductive isolation. We predicted that sympatric females would have denser thoracic sensilla and/or a different spatial pattern of sensilla than allopatric females. We measured sensilla number, density, and pattern of female *E. anna* and *E. caruncuIatum* from 19 populations. We found that although individual sensilla traits vary widely within a population, intraspecific population means are not significantly different in sympatry vs allopatry. Our results suggest that species-specific spatial locations of sensilla may be sufficient for detecting large differences in male morphologies (species recognition), whereas sensilla number may be more important for fine discrimination among conspecific males (sexual selection).

76.7 BARNES, BM*; TOIEN, O; University of Alaska Fairbanks; *bmbarnes@alaska.edu*

Squirrel vs. Bear: Comparting Phenotypes of Mammalian Hibernation

Mammals that hibernate occur in 14 orders including monotremes and primates and vary in size from a few grams to several hundred kilograms. This talk will compare the energetics, thermoregulation, body temperature patterns and resulting constraints in two hibernators that overwinter in Alaska, the arctic ground squirrel and the American black bear. Q: Do bears hibernate in the woods? Some say no, since bears remain at relatively high body temperatures during winter. Ans: Of course they do. Hibernation is an adaptation of avoiding starvation by regulating metabolic demand at low levels; what happens to body temperature is then largely a matter of physics. Hibernating black bears and arctic ground squirrels have identical gram specific metabolic rates under common winter conditions, but because of the bear's relatively low thermal conductance its body temperature averages 34 vs -2 deg C in the ground squirrel. From basal rates, ground squirrels can decrease their metabolism to minima of 2 vs 25% in bears, but both burn mostly fat and lose about 30% of their body mass overwinter. Hibernating ground squirrels but not bears require periodic arousals from torpor to euthermia, although bears display mysterious multi-day cycles of body temperature. Hibernating bears sleep almost all winter whereas sleep is confined to periodic arousals in ground squirrels. Female bears become pregnant, give birth, and lactate during hibernation, while reproduction occurs afterwards in ground squirrels, although males end torpor early to go through puberty. Whether hibernation among different mammal species is an ancestral or derived trait is controversial, but it works equally well in arctic ground squirrels and black bears to get them through long, cold, and dark winters.

48.1 BARON, M; HOSOI, A; WILLIAMS, CD; DANIEL, TL*; Massachusetts Inst. of Tech., Boston, Univ. of Washington, Seattle, Univ. of Washington, Seattle; *danielt@uw.edu*

Flow in the lattice of myofilaments

Muscle contraction occurs in a densely packed lattice of thick and thin filaments with myosin motor molecules utilizing ATP to generate forces. During contraction, the thick and thin filaments slide relative to each other in the axial direction and, as our recent X-ray diffraction evidence suggests, those filaments also move radially. With the assumption that these filaments move in a fluid environment surrounding them, we asked how viscous forces may play a role in the mechanics and energetics of muscle contraction. To address this question we modeled the lattice of filaments and motor molecules using a spatially distributed system of singularities (stokeslets and potential doublets) that satisfy the Stokes equations and continuity. The model specifies filament spacing and size, myosin spacing and size, as well as sliding velocity. From that system we predict both flows and forces associated with contraction as a function of the axial and radial motions. Even with pure axial sliding, conservation of mass leads to radial flows throughout the filament lattice. Thus sliding motions contribute to flux of solutes (such as ADP and ATP) into an out of the filament lattice. Radial motions greatly amplify this flux. To our surprise, however, we find that the associated viscous forces exerted on motor molecules are quite modest: shear forces exerted by a thin filament on a myosin molecule account for less than 1% of the force that can be generated. We suggest that the energy lost by viscous stresses may be offset by the increased delivery of ATP.

26.8 BARRIOS, A/S*; PAIG-TRAN, E/WM; California State University, Fullerton; *abarrios@fullerton.edu*

Freezing Effects on the Anosteocytic Bone of the Pacific Mackerel (Scomber japonicus)

Many biological materials are mechanically tested before any freezing event occurs to prevent structural distortion. However, fish specimens, especially those collected off the coastal shelf, are commonly frozen during transportation to reduce decomposition, which may result in skewed measurements of the mechanical properties compared to fresh samples. We hypothesize that the mechanical properties of the anosteocytic opercular bone of the Pacific mackerel, *Scomber japonicus*, will be affected by freezing events. Mackerel were caught using hook and line in Newport Beach, CA, USA, and separated into three treatments: fresh (n=15), short-term frozen (n=15; 25 days), and long-term frozen (n=15; 45 days). Frozen mackerel were thawed one hour prior to testing. Additional specimens of mackerel (n=15) were purchased from a local grocery store and tested to determine whether store-bought specimens are suitable for mechanical testing. Beams (1 0.25 cm) were cut from each opercle using a Full Spectrum LASER desktop C02 laser, and then subjected to three-point bending tests using an Instron 5942. The stiffness (Young's modulus) and toughness (modulus of resilience) were calculated for each beam using stress-strain curves, and analyzed using a one-way ANOVA and post-hoc Tukey tests. The mechanical properties of the fresh mackerel weren't significantly different from the short-term or long-term frozen mackerel. The store-bought mackerel were significantly stiffer ($p<0.05$) and tougher ($p<0.001$) than all 3 treatments. Our findings show that bone can be frozen during transportation without significantly affecting its properties, however, fish bone collected from grocery stores may have undergone multiple freezing events that make it unsuitable for mechanical testing.

P1.288 BARTLAM-BROOKS, HLA*; ROSKILLY, K; BUSE, C; LOWE, JC; BENNITT, E; HUBEL, TY; WILSON, AM; The Royal Veterinary College, London, ORI, University of Botswana; *hbartlambrooks@rvc.ac.uk*

Determining water intake in wild Plain's zebra (Equus quagga)

The ranging of mammals living in arid environments is limited by their requirement to drink. Physiological adaption amongst these species varies ranging from non-obligate drinkers to animals that drink daily. Whilst Plain's zebra usually drink daily specific populations in arid regions of Botswana drink once every 3-5 days. This adaptation enables them to maximize the time spent in distal grazing grounds where forage is of better quality. Here we set out to devise a method of determining water intake to enable evaluation of the physiology of these specialised zebra. The system consisted of two AMTI forceplates combined to give a sensor area of 1800x600mm. The plates were buried under a game trail leading to/from a water point in the Makgadikgadi N.P., Botswana. Forceplate data were fed to a Raspberry Pi computer buried adjacent to the plates where force data were monitored and recorded. Video data were continuously buffered using a commercial Webcam and clips recorded to the Raspberry Pi whenever animals were moving over the plates. Comparisons were then made of the weights of incoming and outgoing adult animals with correction for faecal loss. There were a number of challenges in deploying the system including enthusiastic investigation by elephants and maintaining a natural environment to ensure continued trail usage. The data generated are of sufficient quality to enable good estimates of intake, allowing the water balance of these specialised zebra to be modelled and improving understanding of the population's resilience in the face of increasing climatic variability.

S10.10 BARTLETT, ME*; AYHAN, D; KLEIN, H; HANDAKUMBURA, P; WHIPPLE, CJ; BABBITT, C; University of Massachusetts Amherst, Brigham Young University; *mbartlett@bio.umass.edu*
Novelty in grass flowers: making the links between molecules and morphology

The grass family is fabulously diverse. Grasses are dominant in terrestrial ecosystems, and the cornerstone of human society because humans are dependent on grasses for grain. The grass flower is highly derived and morphologically specialized for wind pollination. My lab has been working to understand the molecular underpinnings of grass flower specialization, focused in particular on floral organ identity in the grasses, and on the evolution and development of unisexual grass flowers. Our characterization of homeotic organ identity genes in the grasses has shed light not only on the specification of floral organ identity, but has also revealed a complex history of shifting protein-protein interactions between these homeotic transcription factors. I will discuss our work dissecting the consequences of these shifting protein-protein interactions to the evolution of gene regulation. I will also discuss the development and evolution of floral sexuality in the grass family. Unisexual flowers have evolved multiple times in the grasses, from an ancestrally hermaphroditic state. My lab is working to identify and characterize the genes that control unisexual grass flower development, and to understand how these genes have evolved in the grass family.

S1.8 BARTON, Brandon T*; MURRELL, Ebony G; Mississippi State University, Pennsylvania State University; *barton@biology.msstate.edu*
Comparing the effects of climate warming on biological control in conventional and organic agriculture

Studies have shown that organically farmed fields promote natural predator populations and often have lower pest populations than conventional fields, due to a combination of increased predation pressure and greater plant resistance to pest damage. It is unknown how pest populations and predator efficacy may respond in these farming systems as global temperatures continue to rise. To test this, we placed in eight alfalfa fields, four having been conventionally farmed and four organically farmed for 25 years. We stocked cages with pea aphids (Acyrthosiphon pisum) and one of three predator treatments (0, 2, or 4 of the ladybeetle Hippodamia convergens). Half of the cages per field were then either left at ambient temperature or plastic-wrapped to warm them by 2°C. Aphid abundances were similar in conventional and organic fields under ambient conditions, but were significantly higher in conventional than in organic fields when cages were warmed. Predator efficacy was reduced under low predator abundance (H. convergens = 2) in conventional fields under warming conditions; predation strength in organic fields was unaffected by warming. Our study suggests that organic fields may be more tolerant to global warming than their conventionally farmed counterparts, in terms of both pest populations and predator-prey dynamics.

P3.150 BARTS, N*; KEITHLINE, GA; TOBLER, M; Kansas State University; *barts2@ksu.edu*
The Aerobic Scope of an Extremophile Fish and its Significance for Metabolic Physiology in Hydrogen Sulfide Environments

Extreme environments are characterized by harsh physiochemical conditions, resulting in modifications of various facets organismal function in individuals exposed to them. Metabolic physiology is critically important for an organism's ability to respond to environmental stress, as it is directly tied to maintenance costs and energy demand. This may be especially important for organisms that inhabit hydrogen sulfide (H2S) rich environments. The molecule's ability to bind to cytochrome c oxidase (COX) effectively disrupts the electron transport chain and inhibits aerobic ATP production. Theory suggests that this effect should reduce metabolic scope in two potential ways either through direct inhibition of mitochondrial function in presence of H2S, or though adaptive modification of target proteins in the oxidative phosphorylation pathway. We measured the aerobic scope in *Poecilia mexicana* (Poeciliidae), a fish species that has successfully and repeatedly colonized H2S springs in Mexico. Aerobic scope of sulfidic populations with and without H2S-tolerant COX were compared to reference populations from adjacent nonsulfidic habitats. Using intermittent-flow respirometry and exhaustive chase trials, we compared standard metabolic rate, maximum metabolic rate, and aerobic scope between sulfidic and nonsulfidic populations. This allows the testing of how different physiological mechanisms used to cope with H2S impacts metabolic traits. The results of these experiments provide insight into the role metabolic physiology plays in allowing organisms to inhabit and thrive under extreme environmental conditions.

47.5 BASTIN, BR*; KHINDURANGALA, LR; SCHNEIDER, SQ; Iowa State University; *brbastin@iastate.edu*
Tektin evolution and conservation of ciliary function in a spiralian model system

Tektins are a family of microtubule stabilizing coiled-coil domain proteins. As many as five Tektins have been identified in vertebrates where they have been shown to play an important role in sperm flagellar function, while four Tektin homologs in sea urchin are involved in regulating propoer cilia and flagella length and motility. In addition, a single Tektin homolog in the unicellular algae *C. reinhardtii* has been implicated in axonemal defects, indicating an ancient conserved function. While Tektins have been studied extensively in sea urchin and mammals, very little work has been done on Tektin expression and function outside the deuterostomes or on the evolutionary relationships of Tektin proteins throughout the Metazoa. Here we present the first comprehensive phylogenetic analysis of Tektin proteins in the Metazoa as well as the first comprehensive study of Tektin expression in a non-deuterostome model: the polychaete *Platynereis dumerilii*. We find that the last common ancestor of the Metazoa had two Tektins, while the last common ancestor of the bilaterians had four. A duplication event early in the vertebrate lineage gave rise to extant Tektin-3 and Tektin-5, while an independent duplication event early in the spiralian lineage gave rise to Tektin-3/5A and Tektin-3/5B. We show that all five Tektins are likely involved in ciliary function in *P. dumerilii*, with four Tektins expressed in all ciliated cells, while the fifth Tektin, Tektin-3/5B, is expressed only in posterior ciliated cells. Furthermore, hyperciliated embryos treated with Azakenpaullone show expanded expression domains for all Tektins. Thus Tektin involvement in ciliary function is more widely conserved among the Metazoa than previously shown, and future studies in Tektins using spiralian, ecdysozoan and nonbilaterian models may help shed more light on the evolution of cilia in the Metazoa.

32.7 BASU, C*; DEACON, F; WILSON, AM; HUTCHINSON, JR; Structure & Motion Laboratory, Royal Veterinary College, UK, University of the Free State, Republic of South Africa; *cbasu@rvc.ac.uk*

The fast-speed kinematics of wild giraffes, using video derived from an unmanned aerial vehicle (UAV)

Giraffes (*Giraffa camelopardalis*) are ruminant artiodactyls whose large body mass combined with long, gracile limb and neck proportions render them highly specialized in comparison to sister taxa. Previous studies have been confined to describing kinematics from a small number of trials, usually with single individuals. Our previous work has described the kinematics and ground reaction forces from walking giraffes in a zoological park. Here we quantify the kinematics from fast-moving, free-ranging giraffes. We measured kinematic variables (including speed, duty factor, stride length and frequency) from a sample of 35 free-ranging giraffes, from three field locations in the Free State, South Africa. We used an unmanned aerial vehicle (drone) to gather video footage of running giraffes, over a range of body sizes and stages of ontogeny. Each video frame was calibrated using leg length as a known dimension. Leg length was measured using a combination of close range photography, and GPS calibrated ground measurements. Running speeds ranged from 2.8 - 11 m/s. Across the studied speed range, the predominant running gait was a 4-beat rotary gallop with no suspension phase, although gathered suspension was noted in some juvenile individuals. Stride frequency ranged from 1 - 1.4 Hz, and stride length 2.9 - 8.3 m. When compared with other large ungulates (eg. the horse), this pattern illustrates a tendency for conservative stride frequencies in giraffes, where faster speeds are instead achieved by marked increases in stride length.

52.5 BATTISTA, NA*; MILLER, LA; Univ. of North Carolina, Chapel Hill; *nick.battista@unc.edu*

To flow or not to flow: effects of resonant driving and damping on valveless pumping

Impedance pumping (or dynamic suction pumping) drives flow through a flexible valveless tube with a single region of actuation. This pumping mechanism has been proposed as the primary mechanism for inducing flow in the vertebrate embryonic tubular heart. It may also serve as a pumping mechanism in other valveless, flexible tubes such as the intestines, the bodies of swimming salps, and some tubular invertebrate hearts. It is a profoundly complex pumping mechanism given that the flow velocities and directions generated depend nonlinearly upon the driving frequency, material properties, duty factor, and location of the actuation point. We propose that dynamic suction pumping is an efficient mechanism for moving fluid when it is actuated at the tube's natural frequency of vibration and when the tube is not critically damped. We use the immersed boundary method to solve the fully-coupled fluid structure interaction problem of pumping in a flexible tube with and without mass. We find that strong flows are produced when the tube is driven at one of its resonant frequencies and when it is not critically damped.

110.4 BATZEL, G*; MABOLOC, EA; GRÜNBAUM, D; Friday Harbor Laboratories, Hong Kong University of Science, University of Washington; *gbatzel@gmail.com*

Larvae of the echinoid Dendraster excentricus change swimming behavior to avoid low pH in columns with layers of acidified and ambient seawater

The abundance and distribution of many benthic invertebrates depends on success in their larval life-history stage. In the coming century, the world's oceans will drop in pH due to the increased uptake of atmospheric carbon dioxide. Past studies have documented morphological changes in larvae reared under elevated pCO_2 conditions. Larvae might minimize exposure to low pH by modifying swimming behaviors. However, larval swimming responses to boundaries between acidified and normal seawater remains unknown. We quantified vertical distributions of larvae of the sand dollar *Dendraster excentricus* released from the bottom of a stratified column with a layer of ambient seawater over- or underlying a layer of acidified seawater. As larvae approached a transition from normal to acidified water, they exhibited twirling swimming behavior followed by downward swimming. Larvae transitioning from low pH to normal seawater maintained upward swimming. In both cases, larvae used swimming responses to substantially avoid acidified seawater. The results of this study imply behavioral avoidance of low pH water masses by larvae that may have important ramifications for the distribution of both larval and adult marine invertebrates in the coming century.

39.3 BAUER, CM*; GRAHAM, JL; ABOLINS-ABOLS, M; HEIDINGER, BJ; KETTERSON, ED; GREIVES, TJ; North Dakota State University, Indiana University, Indiana University; *carolyn.m.bauer@ndsu.edu*

Early breeding female Dark-eyed Juncos (Junco hyemalis) have shorter telomeres

In female birds, timing of clutch initiation is controlled by both external (e.g. photoperiod, temperature, food availability) and internal (e.g. body condition, endogenous circannual rhythms) factors. Internal factors representative of remaining lifespan may also influence seasonal timing of reproduction in female birds, as individuals that breed earlier in the season generally have greater reproductive success. However, evidence suggests that breeding early may be costly. Therefore, it may be expected that females with fewer future reproductive events are more likely to breed early in the season. While chronological age is a good indicator of remaining lifespan, telomere lengths may be a better biomarker of longevity as they reflect both chronological age and potentially lifetime oxidative stress exposure. We examined whether variation in the timing of first clutch initiation was related to telomere length in female Dark-eyed Juncos (*Junco hyemalis*). We found that in female juncos with prior reproductive experience, there was a correlation between telomere length and the date on which the first egg was laid such that early breeders had shorter telomeres. These results are consistent with our hypothesis that early breeders have a shorter remaining lifespan, and suggest that birds may adjust their current reproductive effort based on lifetime physiological wear-and-tear. Alternatively, if timing of clutch initiation is repeatable among individuals, shorter telomeres in early breeders may reflect the costs of breeding early the previous season.

P2.81 BAUER, CM*; GRAHAM, JL; GREIVES, TJ; North Dakota State University; *carolyn.m.bauer@ndsu.edu*

Hypothalamic-pituitary-adrenal axis regulation differs between fall and spring migration

During spring migration, long-distance migratory birds fly faster, have higher refueling rates at stopovers, and are more likely to encounter inclement weather compared to fall migration. Together, these observations suggest that migration is likely more challenging in the spring than the fall. As the hypothalamic-pituitary-adrenal (HPA) axis helps vertebrates appropriately respond to environmental challenges and stressors, we examined whether HPA-axis activity and regulation differed between fall and spring migration in a long-distance migrant. We measured baseline corticosterone (CORT), stress-induced CORT, and negative feedback efficacy in migratory, slate-colored Dark-eyed Juncos (*Junco hyemalis hyemalis*) during their fall and spring stopovers in Fargo, North Dakota. Spring migrants had higher body weight, fat stores, and hematocrit compared to fall migrants. While baseline and stress-induced CORT did not significantly differ between fall and spring stopovers, migrants had weaker negative feedback in the spring. These findings fit well with the hypothesis that HPA-axis activity helps mediate initiation of breeding (the CORT-Flexibility Hypothesis), and suggest that stress sensitivity may help individuals appropriately respond to prevailing environmental conditions and alter timing of reproduction after arrival to the breeding grounds.

P3.201 BAUMGART, SL*; WESTNEAT, MW; Univ. of Chicago; *slbaumgart@uchicago.edu*

Geometric morphometric analysis of the avian wing and sternum

Two factors central to flight mechanics in birds are muscle forces exerted by the pectoralis on the wing and wing shape that governs its aerodynamics. Although the sternum serves as the anchor for the pectoralis, comprehensive morphometric analysis of sternum size and shape across birds has yet to be undertaken. Previous work has shown that birds with a large keel are adept fliers, while birds with a reduced or absent keel typically are flightless, and that avian sterna may be classified into three locomotor modes (swimming, flying, and walking). How sternum shape varies phylogenetically or ecologically remains to be explored. Wing shape in birds is correlated with flight strategy and ecology as shown by a simple aspect ratio: elongate wings are associated with soaring, broad wings with maneuverability, and short, pointed wings with speed. In this study, a series of geometric morphometric analyses were performed on the dorsal, ventral, lateral, and anterior views of a wide range of avian species to better correlate sternal shape with flight strategy. These studies have been compared with geometric morphometric data collected on wing shapes to determine whether there is a correlation between sternum shape and wing shape. Preliminary results show that high aspect ratio wings have evolved multiple times independently with significant phylogenetic signal across the bird tree for wing shape. The morphology of the sternum also clusters strongly in relation to lifestyle and phylogeny with a complementary pattern to that of wing shape analyses. This suggests that although wing shape is important for studying avian evolution and adaptation, sternal morphology should also be taken into account and analyzed in concert with the wing in order to test hypotheses of coevolution among functional traits and convergence across bird phylogeny.

P2.31 BEANS, AL*; DUELL, ME; HARRISON, JF; Arizona State University; *205abeans@gmail.com*

Thermal Tolerance Varies with Body Size in Orchid Bees

As climate change drives historically stable air temperatures upward, the effects on ectotherms may be severe. Animal body size affects responses to many environmental factors; however, it is not clear whether body size affects organismal responses to environmental temperature. Recent studies (Oyen et al. 2016; Kaspari et al. 2015), found that organisms could survive higher air temperatures during thermal ramping, but attributed these size effects to biophysical factors such as larger ants having longer legs and larger bees being slower to equilibrate while ramping. We determined the acute critical thermal maximum temperatures for orchid bees (n=61) that varied in body mass from 0.0573-1.0248 grams. Orchid bees were caught by baiting to odor compounds in Gamboa, Panama. Bees were immediately transported to a lab at The Smithsonian Tropical Research Institute in Gamboa where we placed them in a small arena inside a sealed styrofoam cooler. We continuously measured air temperature as it was ramped upward, recorded changes in behavior relevant to thermoregulation throughout warming, and measured air and bee thorax temperatures using a grab and stab method immediately following death. We found that larger orchid bees had slightly higher critical thermal maxima than smaller bees. Contrary to the prior cited studies, our results cannot be explained by biophysical factors, since unlike prior studies, we measured body temperatures at the time of death and these were higher in larger bees. Also, the elevation of body above air temperature increased in larger bees. We hypothesize that, since larger bees are warmer than the smaller bees at all air temperatures, that larger bees may have evolved the ability to tolerate higher body temperatures, they might be less sensitive to elevated air temperatures.

44.1 BECK, ML*; DAVIES, S; SEWALL, KB; Virginia Tech; *beckmichelle@gmail.com*

Does melanin-based coloration signal quality in song sparrows? Associations between melanin, hormones, condition, and behavior

Expression of melanin-based coloration is associated with a number of plastic physiological and behavioral traits including concentrations of sex and stress hormones, immune responses, and territorial aggression. One potential mechanism that could produce these relationships is condition-dependent signaling in which case individuals with larger or darker ornaments should be in better condition during molt or better able to bear the cost of displaying the ornament. Recently, it has been suggested that these associations could arise due to pleiotropic effects associated with melanin synthesis. We examined these relationships in male song sparrows, which possess melanin-based spotting on their breast. Specifically, we quantified (1) the size and reflectance of the spotting, (2) baseline and gonadotropin releasing hormone (GnRH) induced concentrations of testosterone (T), (3) baseline corticosterone (CORT) concentrations, (4) territorial aggression in response to playback, and (5) bacteria killing ability (BKA) as a measure of innate immunity and (6) male condition during molt using growth bars. We found that GnRH induced T concentrations were positively associated with male badge size. Additionally, males with lighter badges displayed more aggressive behavior toward the playback than males with darker badges. Neither BKA nor the rate of feather growth during molt were related to badge size or color and the latter result suggests that condition during molt does not affect the expression of this ornament. These results indicate that pleiotropic effects associated with melanin synthesis could underlie for some aspects of male phenotype in song sparrows.

P1.50 BECK, ML*; HOPKINS, WA; University of Massachusetts Lowell, Virginia Tech; *beckmichelle@gmail.com*

The relationship between plumage coloration and aggression in female tree swallows

Intrasexual competition is an important selective force that can favor the evolution of honest signals of fighting ability or dominance. Competition for breeding and non-breeding resources occurs in both sexes, but research in this area focuses predominantly on males. However, females in many taxa possess ornaments or armaments that could mediate the outcome of female competitive interactions. Plumage coloration is one such ornament and in males the size and/or reflectance of plumage areas is associated with the outcome of male competitive interactions. We examined the relationship between blue and white structural coloration and aggression in female tree swallows (Tachycineta bicolor). We assessed aggression by placing a caged second-year (SY) female tree swallow 2 m from the nest box of a focal female and quantified the focal female's response. We predicted that females with brighter white and brighter and bluer plumage would respond more strongly to the intruder. Contrary to our prediction, we found no relationship between blue coloration and aggressiveness towards the intruder. Rather, females with dull white breast coloration responded more strongly to the intruder whereas females with bright white breasts spent more time perched on their nest box. These results indicate that plumage color in female tree swallows may not be a honest signal of aggressiveness. Rather, dull white females may be more motivated to defend their nest site or may perceive a SY female intruder as a greater threat than females with bright white breasts.

104.4 BECKER, DJ*; STREICKER, DG; ALTIZER, SA; University of Georgia, University of Glasgow; *dbecker@uga.edu*

Host movement ecology and feeding behavior influence how resource provisioning affects parasitism for wildlife

Food provided by human activities such as agriculture, recreational feeding, and conservation management can be less seasonal and more spatially reliable than natural resources, and subsequent changes to wildlife ecology can have profound impacts on host-parasite interactions. Wildlife species vary not only in their propensity to capitalize on anthropogenic food, but also in how their behavior and physiology respond to greater food availability. Here we conduct a phylogenetic comparative analysis of 284 host-parasite interactions across 55 wildlife species to identify species-level traits that influence whether resource provisioning increases or decreases measures of parasitism. Accounting for shared evolutionary history of wildlife species and uneven sampling effort, we found that effect sizes for bacteria, viruses, protozoa, and fungi were correlated with host home range, trophic level, and migratory status, suggesting wide-ranging species, herbivores, and migrants are prone to have increased microparasitism with supplemental feeding activities. In contrast, effect sizes for helminths and ectoparasites showed more variation that was partly explained by host dietary diversity. Generalist foragers had reduced macroparasitism with supplemental feeding, suggesting these species can shift foraging away from natural foods that serve as intermediate hosts toward parasite-free anthropogenic resources. This analysis suggests that movement and dietary traits affect which host species experience greater parasitism under resource provisioning and highlights certain taxa for which parasite surveillance could be targeted or supplemental feeding could be limited to reduce infectious disease risk.

2.3 BECKERT, M.*; FLAMMANG, B. E.; NADLER, J. H.; ANDERSON, E.; Georgia Tech Research Institute, New Jersey Institute of Technology, Grove City College; *michael.beckert@gatech.edu*

Computational Drag of an Attached Remora

Remora fishes possess a unique dorsal pad capable of forming reversible, suction-based attachment to a variety of host organisms and marine vessels. Although several investigations of the suction pad have been carried out, much less attention has been given to fluid drag despite it being the principal force that remoras must resist. Here a theoretical estimate of the drag experienced by a remora attached to a host is presented using computational fluid dynamics (CFD) informed by actual remora geometry obtained from micro-computed tomography. The simulated flows were compared to measured flow fields of a euthanized specimen in a flow tank. Additionally, the impact of the host's boundary layer was investigated, and scaling relationships between remora features were computed from the digitized geometry. The results suggest the drag on an attached remora is analogous to that of a non-lifting, streamlined body with the host's boundary layer playing a minimal role. Consequently, this evidence does not support previous hypotheses that remoras choose attachment locations for hydrodynamic considerations. Comparison of the simulated drag with experimental friction tests showed that, even at elevated swimming speeds, it is unlikely a remora will be dislodged solely by drag forces, and furthermore that larger remoras are more likely to remain attached to a host than smaller remoras at the same swimming speed. This may indicate remoras become more suited to attachment as they mature.

P1.30 BEDORE, CN*; WEGNER, NC; Georgia Southern University, Southwest Fisheries Science Center; *cbedore@georgiasouthern.edu*

Body Temperature, Cerebral Vasculature, and the Potential for Brain Warming in Cownose Rays (Rhinoptera bonuses)

The visual system of the cownose ray (*Rhinoptera bonuses*) demonstrates temperature sensitivity similar to that of cranially endothermic billfishes. Although physiological mechanisms that support cranial endothermy have not been identified in batoids, previous authors have described a pre-cerebral rete in some species of derived Myliobatids. The function of the pre-cerebral rete has been assumed to play a role in cranial thermoregulation. Upon gross and histological examination, we confirmed that *R. bonuses* brains possess an extensive vascular network, extending anteriorly to perfuse the olfactory structures, ventrally to the saccus vasculosus, and posteriorly to the thyroid gland. However, the network was composed of branching arteries that did not directly contact one another as is typical of countercurrent heat exchanging retia, which conduct heat between arterial and venous blood. Field-based temperature measurements from freshly landed rays were inconclusive and raise speculation that the pre-cerebral rete contributes to brain temperature regulation. Though temperatures across the body were elevated 1-3°C above ambient, these measurements are lower than those reported for other thermoregulating fishes. Elevated temperatures from cownose rays may reflect either the production of heat by the red muscles or the retention of that heat for thermoregulation. Ongoing field temperature measurement data will be supplemented by thermal manipulation experiments. Future work will model the extent to which *R. bonuses* may produce or retain heat, as well as investigate the potential for elevated body temperatures to contribute to brain warming.

P1.198 BEECHKO, A*; AZIZI, M; GARLAND, T; HORNER, A; California State University, San Bernardino, Univ. of California, Irvine, Univ. of California, Riverside; *beechkoa@gmail.com*
Changes in muscle properties as a function of age and training in mice
Muscles adapt quickly to perturbations such as exercise training, disuse, or aging. Advanced aging is associated with a decline of muscle performance , whereas training results in enhanced contractile properties of muscle and metabolic changes that benefit performance. While numerous studies have documented age-related declines in muscle and locomotor performance, it is still unclear how factors such as extreme, lifelong aerobic training and genetics can impact the timing and trajectory of muscle aging. Here we use mice from two genetic lines (control and mice selected for high levels of wheel running over 70 generations, or HR mice) to better understand the effect of high levels of aerobic activity on age-related declines in muscle performance. Mice were divided into four cohorts (Ctrl/wheel access, Ctrl/no wheel access, HR/wheel access, HR/no wheel access) and muscle contractile properties were obtained from mice at time points spanning two years for each cohort. In order to characterize contractile performance we used an in situ preparation to measure the force, velocity, power, and passive properties of the triceps surae complex. We found that, without training, control mice had significantly higher shortening velocities than HR mice, regardless of age. There were no significant differences in power production, force, or resilience across any line or treatment cohort. We found that passive stiffness significantly declined across all mice with wheel access in late ontogeny. This study informs our understanding the role of endurance training in preserving a healthy muscle phenotype throughout ontogeny. Our results may also provide insight into relative contributions of genotype and phenotypic plasticity as mechanisms that determine how muscles respond to training and aging.

P3.97 BEECHUM, TJ*; RUPP, TM; MARTIN, AL; Saginaw Valley State University, Michigan State University; *tjbeechu@svsu.edu*
The relationship between shelter density and aggression in the rusty crayfish, Orconectes rusticus
Shelters are an important resource for animals as they provide protection from the elements, predators and conspecifics. Animals often engage in aggressive interactions when competing for access to shelters. Aggression seems to correlate well with the spacing and density of shelters in various animal systems; dominant individuals have been shown to display more aggressive behaviors when shelters are closer together. While there have been studies that have examined the effects of both density and abundance on aggression, in crayfish, few studies have analyzed density independently to observe its influence on these behaviors. For this study three tanks of varying diameters, (152.4 cm, 91.44 cm and 60.96 cm) were setup with 4 shelters that were evenly spaced throughout each environment. Four crayfish were placed in each experimental setup and allowed to interact for a period of 24 hours. The density of shelters correlates directly with the size of the experimental tank (smaller tanks represent a denser shelter configuration than larger tanks). Agonistic interactions between the crayfish are being quantified to assess the number of aggressive encounters, maximum intensity of each encounter, and the number of shelter evictions in each experiment. The goal of this study is to assess how shelter density impacts agonistic interactions within populations of the crayfish, *Orconectes rusticus*.

P3.124 BEHRING, R/S*; GOFORTH, R/R; BEHRING, ROBERT; Purdue University; *rsbehring@gmail.com*
Predation Efficiency and Reactive Distance of Pacific Red Lionfish (Pterois volitans) Under Varied Light and Turbidity Regimes
Invasive Pacific red lionfish (*Pterois volitans*) have been shown to substantially reduce native fish recruitment in introduced coral reef ecosystems. However, the potential for these fish to invade and affect other ecosystems, such as estuaries and mangals, have not been studied. We hypothesize that lowered visibility caused by characteristic turbidity in the waters of these ecosystems serves as an impediment to their invasion success due to expected reliance on visual cues for predation success. We are testing this hypothesis by evaluating reactive distance, calculations of predation efficiency (number prey eaten/hour), and total prey eaten by laboratory maintained lionfish using mummichogs (*Fundulus heteroclitus*) and grass shrimp (*Palaemonetes sp.*) as model prey. We are using a t5 fluorescent lamps and Rosco lux light filters to adjust light levels from 0-5000 lumens to observe lionfish predation over a 24-hr period. We also expect to conduct the same series of experiments under varying levels of turbidity (0-1000 NTU) induced by suspending bentonite clay in the water column. We expect our results to reveal that lionfish predation success is dependent on visibility, suggesting that low visibility habitats are unlikely to be invaded and affected to the same degree seen in Caribbean coral reefs.

P2.200 BEINTEMA, DP*; DAVIS-BERG, EC; Lake Forest College, IL, Columbia College Chicago, IL; *edavisberg@colum.edu*
Survey of gastropods from Breidenthal Biological Reserve, an Eastern deciduous forest in Baldwin Woods Forest Preserve in Kansas
The University of Kansas' Breidenthal Biological Reserve is located near Baldwin in Douglas County, Kansas. This area is wooded, specifically Eastern deciduous forest comprised mostly of oak and hickory, and is not known to have been used for farming or grazing. It is likely that the woods were logged for large Walnut and Oak trees prior to the 1960's. This area is part of the Douglas Group of sedimentary rock which includes sandstone and shale as well as limestone (Wells and Morley 1964). The University of Kansas purchased the woods in 1965. There are no known surveys of gastropods from this site. Two separate sites were each sampled in 2007 and 2015. The sites were identified with GPS coordinates. These surveys will provide a first species list for Breidenthal, and can be used as baseline gastropod species information for wooded temperate forests within the Midwestern United States. Our estimates of snails from 2007 were 656 snails per square meter for site 1 and 1,888 snails per square meter for site 2. Site 1 is near a creek bed and Site 2 is in a wooded location. We have compared our findings to previous work at the Fitch Natural History Reservation which is also within Douglas County, Kansas where snails at wooded sites ranged from 256 - 2368 snails per square meter. In addition, our data can be used in future surveys of Kansas and surrounding areas as a comparison to other ongoing snail biodiversity research in the region.

P3.139 BELL, MM; Texas State University; *mmb151@txstate.edu*
Comparison of Fine Scale Vegetative Parameters at Active and Inactive Gulf Coast Kangaroo Rat Burrow Sites
The Texas endemic Gulf-coast kangaroo rat (*Dipodomys compactus*, GCKR) belongs to the family Heteromyidae and ranges from Mustang and Padre Islands inland to Bexar and Gonzales counties in Texas. Although listed as globally secure by the International Union for Conservation of Nature, it is listed as vulnerable on Texas Parks and Wildlife Conservation Action Plan. Despite the need to develop holistic management plans for inconspicuous/understudied species, few ecological studies on habitat requirements have been conducted on GCKR. Since April 2016, I have monitored seasonal changes in vegetation and GCKR burrowing activity at 63 randomly selected sites on a working ranch located in Guadalupe County. I recorded monthly data at sites occupied by GCKR in April 2016 and occupied thereafter. I recorded percent cover using the Daubenmire frame and cover estimate technique. I also identified dominant species of forbs and grasses and recorded percent woody canopy cover. From the site center, I measured distance to the nearest burrow complex and woody canopy cover. At this time, 19 of 63 sites had active burrows for at least one month. For active and inactive/non-burrow sites, canopy cover was 1% and 29% and distance to the nearest canopy was 64m and 35m, respectively. Percent cover of bare ground (29% vs 13%) and forbs (32% vs 19%) was higher at active compared to inactive sites. At inactive sites, percent cover of litter (33% vs 14%) and grasses (25% vs 20%) was higher than at active sites. Standing dead herbaceous cover was similar. The dominant herbaceous species for active sites were Lazy Daisy (*Aphanostephaus spp.*), Rosette Grass (*Dichanthelium spp.*), and Thin Paspalum (*Paspalum setaceum*), while Little Bluestem (*Schizachyrium scoparium*), Rosette Grass, and Woolly Croton (*Croton capitatus*) were dominant for inactive sites.

P1.46 BELLES, AP*; HUCKANS, J; KLINGER, TS; HRANITZ, JM; Bloomsburg University of Pennsylvania; *jhranitz@bloomu.edu*
Call Characteristics Of Island And Mainland Fowler's Toad
With many advantages, vocalization is perhaps the most common form of communication used by vertebrates. Anurans use advertisement calls to acquire mates, thereby affecting both male fitness and premating reproductive isolation. *Anaxyrus fowleri* or Fowler's toads, are abundant on the coastal plain of the eastern USA and inhabit both the mainland and barrier islands of the Atlantic Coast. Previous studies reported island dwarfism in populations of *A. fowleri* on mid-Atlantic Coast barrier islands. Our goal was to test for an association between the small body size of island toads and vocal characteristics of island males. The advertisement calls for 31 mature males were recorded during the breeding seasons of 2010 and 2012, from both island and mainland sites along the Eastern Shore of Virginia. Calls were imported into RavenPro 1.4 to extract data on 12 different call variables. These variables were analysed by principal components analysis (PCA) to study the relationships among the call characteristics. Each call characteristic was also analysed with repeated measures nested ANOVA, to test for differences between island and mainland toads. The PCA indicated that the first two components were responsible for explaining 43% of the total variation in advertisement calls among sites. Six variables loaded on the Principal Component (PC) 1: resonance bandwidth, intensity modulation, lower delta side band, detuning parameter, call length, and the damping parameter. Fundamental frequency, resonant frequency, frequency range, and beginning pulse duration loaded on PC 2. The ANOVA tests indicated differences in resonant frequency between the island and mainland populations. These results support the hypothesis that island dwarfism affects the advertisement calls of these toads.

P2.256 BELOTT, C.*; SKOLIK, R.; MENZE, M. A.; University of Louisville; *cjbelo01@cardmail.louisville.edu*
LEA Proteins Protect Drosophila melanogaster Cells during Prolonged Periods of Desiccation and Osmotic Stress
LEA proteins are highly hydrophilic, intrinsically disordered proteins that are critically important for the survival of a variety of small anhydrobiotic invertebrates during desiccation. LEA proteins found in *Artemia francicana* are comprised of groups 1, 3 and 6. The precise physiological function of LEA proteins during osmotic stress and desiccation is poorly understood. The aim of this study was to assess how the expression of one or more LEA proteins impacted the viability of Kc167 (*D. melanogaster*) cells during prolonged osmotic stress or desiccation. Relative drying times were determined by desiccating Kc167 cells at three different relative humidities (RH) (0%, 32.5%, and 75.5%). Times to reach similar residual moisture contents in cell samples increased with increasing relative humidity. Cell viabilities after desiccation were found to depend on both residual moisture content and drying time. Kc167 cells were stably transfected to express *Afr*LEA3m-mCherry (group 3) and *Afr*SMP-GFP (group 6) concurrently. In addition, expression of *Afr*LEA2 (group 3) or *Afr*LEA3m without fluorescence tags was also achieved. After prolonged desiccation at 75.5% RH, Kc167 cells expressing both *Afr*LEA3m-mCherry and *Afr*SMP-GFP outperformed cells expressing *Afr*LEA3m alone. However, both transformed cell lines showed significantly higher viabilities than control cells. In addition, cells expressing *Afr*LEA2 showed higher viability than control cells after both 24h and 48h of prolonged osmotic stress. Surprisingly, *Afr*LEA3m demonstrated no such protection. These data suggest expressing multiple LEA proteins simultaneously can further enhance desiccation tolerance and that LEA proteins from the same classification group may serve different protective roles (NSF *IOS*-1456809/1457061).

31.6 BEN-EZRA, N; HARRIS, N; BURNESS, G*; TRENT UNIVERSITY; *garyburness@trentu.ca*
Constant and Cycling Incubation Temperatures Affect the Mass, Size, and Metabolic Rate of Adult Japanese quail.
The temperature at which eggs are incubated can have wide-ranging effects on the development of young birds. However, the role that cycling incubation temperatures may play in phenotypic variation is less studied. We incubated Japanese quail eggs at control (37.5°C) and low (36.0°C) temperatures, and under a cyclical temperature regime (which had the same average incubation temperature as the low temperature treatment, and a high temperature that was the same as the controls). We then followed the development of hatchlings to adulthood. As adults, individuals incubated in the low temperature treatment were lighter and smaller than those in the control group, but had higher basal metabolic rates (BMR) than individuals in the cyclical group. Cycling incubation temperatures offset the effects of a constant low incubation temperature on BMR, but not on mass or size. Because embryonic metabolic rate was the same across treatments, the differences we observed in BMR among adults presumably occurred during post-hatching development. Our results highlight the importance of incubation temperature and its pattern on morphological and physiological variation in adult birds.

P1.183 BENITEZ, LM*; JONES, KE; PIERCE, SE; Museum of Comparative Zoology and Department of Organismic and Evolutionary Biology, Harvard University, Cambridge MA 02138; *lbenitez@college.harvard.edu*

Vertebral anatomy and Locomotor Evolution in Mammals: A Geometric Morphometric Approach

Mammalian locomotion relies on bending in the dorsoventral plane to achieve asymmetric gaits, which increase speed and facilitate respiratory-locomotor coupling. This is in contrast to other amniote groups (i.e., lepidosaurs) which emphasize lateral bending during locomotion. To enable this behavior, the mammalian trunk is highly specialized. In particular, the anatomy of the ribless lumbar region promotes dorsoventral mobility, and thus is central to the evolution of fast gaits in mammals. To understand the link between vertebral anatomy and mammalian locomotion, we quantitatively examined vertebral variation across a broad sample of mammals, and compared it to that of lepidosaurs and archosaurs. We compared vertebral anatomy among synapsids and diapsids using 3D geometric morphometrics (n=48, 250 vertebrae). Sixty-four landmarks were taken, including 44 fixed and 20 sliding semilandmarks, at five vertebral positions. Variation was examined using Principal Components Analysis, within extant groups and across the amniote clade. The influence of vertebral position, body size and phylogenetic relationships was examined. Comparisons of extant taxa (36 mammals, 12 diapsids) revealed significant variation based on vertebral position and locomotor mode. Mammals had the greatest intracolumn variation, due to their extreme dorsal regionalization. Variation between taxa is greatest in the lumbar region, while thoracic vertebrae tends to sort phylogenetically. Implications for mammal evolution are discussed.

P1.103 BENNETT, MM*; RINEHART, JP; YOCUM, GD; GREENLEE, KJ; North Dakota State University, USDA-ARS; *meghan.bennett@ndsu.edu*

Keeping rhythm: Environmental cues mediate the emergence of an important pollinator, the alfalfa leafcutting bee, Megachile rotundata

Organisms rely on exogenous cues to entrain their biological rhythms to daily and seasonal fluctuations of the environment. Circadian outputs are mediated by a zeitgeber, which resets molecular feedback loops referred to as clocks. Common zeitgebers found across organisms are the lengths of night and day. Temperature fluctuations can also entrain these feedback loops. The alfalfa leafcutting bee, *Megachile rotundata* is a pollinator used in commercial farming. It is commonly reared under artificial temperatures with no daily fluctuations. Despite the widespread use of these thermal treatments, little is known about how adult emergence is mediated by environmental cues. Adults emerge from a maternally-made brood cell within a cavity where conditions may vary from the external environment. We found that 20-40% of light penetrates the brood cell and internal brood cell temperatures can differ by 2-3°C from ambient conditions. We hypothesized that emergence from the brood cell is predominately controlled by temperature instead of photoperiod, due to their cavity-nesting life history. In contrast to our hypothesis, adult emergence patterns from the brood cell are affected by day length, with longer days entraining emergence more than shorter days. Furthermore, we found *M. rotundata* can quickly respond to a changing environment when exposed to constant conditions then exposed a zeitgeber, where temperature fluctuations greatly impacted emergence rhythms, depending on the amplitude of fluctuations. This knowledge is crucial for understanding the effect of a changing climate on clocks mediating emergence rhythms of pollinators.

P2.109 BENNETT, DJ*; JOHNSON, EE; WENKER, ES; DECAVEL-BUEFF, E; DAVIDSON, BA; MALISCH, JL; W.M. Keck Science Department, The Claremont Colleges, University of Montana, St. Mary's College of Maryland, St. Mary's College of Maryland; *jlmalisch@smcm.edu*

Acute Stress and Hyperglycemia in White-crowned Sparrows

All organisms experience stressors, and the physiological response to stress is highly conserved in vertebrates. Acute stress activates the hypothalamus pituitary-adrenal axis, increasing glucocorticoids (CORT), and promoting glucose mobilization. While this is a generalized phenomenon in mammals, a number of factors, ranging from time of day to blood loss, can change the extent to which acute stress leads to hyperglycemia in birds. Here we characterized the glycemic response to acute-handling stress in a free-living population of white-crowned sparrows (WCSP: *Zonotrichia leucophrys*) in Tioga Pass Meadow, California. We quantified blood glucose in two groups of WCSP: 1) WCSP serially bled at baseline (within 3 min of capture), at 15 min, and at 30 min post-capture and 2) WCSP held for 30 min and bled at 30 min. We found that acute-handling stress elevated blood glucose at both 15 and 30 min post-capture as compared to baseline. Furthermore, there was no difference between blood glucose levels at 30 min in WCSP from group 1 vs. group 2, handling for thirty min without bleeding had the same hyperglycemic effect as handling with serial bleeds. Next, we will examine the glucocorticoid response to stress, including quantification of corticosterone binding globulin (CBG) levels, to determine which predictive variable: baseline CORT, stress-induced CORT, CBG, free CORT, body condition and/or time spent in traps, best predicts variation in stress-induced hyperglycemia.

P2.148 BENNICE, C.O.*; BROOKS, W.R.; RAYBURN, A.P.; HANLON, R.T.; Florida Atlantic University, Florida Atlantic University , Marine Biological Laboratory ; *cbennice@fau.edu*

Behavioral Dynamics of Niche Partitioning between Two Octopus Species in a Shallow Coastal Environment

Identifying how species coexist is central to understanding community structure and biodiversity, and niche partitioning is one such mechanism. Species may use one or multiple mechanisms such as spatial partitioning, habitat partitioning, temporal partitioning, diet partitioning, or morphological partitioning. Two species of octopus (*O. vulgaris* and *M.defilippi*) inhabit a South Florida intracoastal waterway. The following aspects were examined: (1) spatial distribution of occupied dens, (2) influence of habitat heterogeneity for micro- and immediate habitat, (3) foraging behaviors, (4) foraging times and (5) diet. Octopus den locations were marked by GPS to quantify spatial patterns within and between species. The influence of habitat heterogeneity was determined by quantifying substrate composition for microhabitat (1.00 m^2 around den) and immediate habitat (0.13 m^2 directly over den). Video was used to score foraging behaviors and 24h-video determined octopus foraging cycles. Results demonstrate spatial overlap between the species. Micro- and immediate habitat are different between species; *M.defilippi* exploits open sand habitat mainly diurnally and uses flounder swimming mimicry to forage longer distances. *O. vulgaris* uses parachute attack and spends more time foraging on rock and rubble, mostly nocturnally. This study identifies ecological and behavioral components that facilitate coexistence of sympatric species, provides insight into cephalopod ecology and baseline conservation requirements for unique sand-dwelling organisms.

P2.254 BENRABAA, S.A.M*; DAS, S.; MYKLES, D.L.; Colorado State University; *saabmora@rams.colostate.edu*
Regulation of Halloween and ecdysone-responsive genes in molting gland of the blackback land crab, Gecarcinus lateralis
Molting is necessary for growth and development in all arthropods. Halloween genes are expressed in the molting gland (Y-organ or YO) and encode enzymes that catalyze the synthesis of ecdysteroid hormones that coordinate molting processes during the premolt stage. The YO transitions through four physiological states over the molt cycle: basal (intermolt), activated (early premolt), committed (mid to late premolt), and repressed (postmolt). mTOR activity is required for YO activation and TGFβ/Activin signaling mediates YO commitment. Contigs encoding six of ecdysteroidogenic genes (*neverland*, *phantom*, *disembodied*, *spook*, *shadow*, and *Cyp18a1*) were identified in the YO transcriptome. Sequences were validated by Sanger sequencing of PCR products. RNA-Seq data showed that relative mRNA levels of Halloween genes were highest in intermolt and early premolt and then decreased during mid and late premolt to their lowest levels 10 days postmolt. Ecdysteroid receptor (EcR/RXR) binds active molting hormone, which induces serial activation of ecdysone-responsive genes. Insect gene sequences were used to extract seven orthologs from the land crab YO transcriptome: *Broad Complex*, *E75*, *E74*, *Hormone Receptor 4*, *Hormone Receptor 3*, *forkhead box transcription factor*, and *Fushi tarazu factor-1*. The presence of EcR/RXR and ecdysone-responsive genes suggest that elevated ecdysteroid represses the YO at the end of premolt. Using RNA-Seq and qPCR, we will quantify the effects of molting, mTOR inhibitor (rapamycin), and Activin receptor antagonist (SB431542) on gene expression. Supported by NSF (IOS-1257732).

S3.6 BENTLEY, GE; UC Berkeley; *gb7@berkeley.edu*
Neural versus gonadal GnIH: Are they independent systems?
Gonadotropin−inhibitory hormone (GnIH) acts to inhibit reproduction at all levels of the hypothalamo−pituitary−gonad (HPG) axis. For example, GnRH neurons express GnIH receptor and decrease firing in response to GnIH application. The anterior pituitary gland of all species studied also expresses GnIH receptor, and GnIH application decreases pituitary gonadotropin synthesis and release. The gonads of all species studied synthesize GnIH and express its receptor, and GnIH can influence gonadal steroid production directly. Exposure to different stressors causes changes in GnIH expression in the hypothalamus and gonads in birds and mammals in vitro and in vivo. GnIH neurons also express glucocorticoid receptor. Thus, GnIH may be involved in stress-induced reproductive inhibition. Here I discuss regulation of GnIH in the avian brain and gonads in response to different stressors and compare our findings to those in mammals. Our data suggest that GnIH responsiveness to cues of stress appears to be conserved across species, but the response of specific tissues and the direction of GnIH regulation can vary. Importantly, the gonads can respond to cues of stress independently from neural input.

44.3 BENTZ, AB*; NIEDERHUTH, C; CARRUTH, L; NAVARA, KJ; University of Georgia, Athens, GA, Georgia State University, Atlanta, GA; *abbentz@uga.edu*
The Mechanistic Role of Maternal Hormones in Programming Offspring Aggression
A mother's hormonal response to her environment can cause permanent changes in her developing offspring, potentially determining whether those offspring succeed in a given environment. Females breeding in more competitive environments tend to transfer more testosterone to their offspring prenatally, which permanently makes offspring more aggressive. This maternal effect may help offspring adapt to competitive environments, yet it is still unclear how maternally derived testosterone is able to permanently affect offspring behaviors. Without knowing the mechanisms, it is difficult to characterize the heritability of this maternal effect and how it fits into larger evolutionary frameworks. In this study, we have injected captive zebra finch (*Taeniopygia guttata*) eggs with a control vehicle or testosterone and measured aggressive and competitive behaviors in the resulting offspring. We found that offspring from testosterone-injected eggs grew faster, begged longer, and were more aggressive. In a subset of male and female offspring from both treatments, we tested for genome-wide differences in mRNA expression and site-specific methylation patterns in two socially-relevant brain regions, the nucleus taeniae of the amygdala and hypothalamus. This research is among the first to test if molecular mechanisms, such as stable changes in gene regulation (i.e., DNA methylation), underlie the programming of offspring aggression by maternal hormones in songbirds.

84.1 BERGMANN, PJ*; PETTINELLI, KJ; CROCKETT, ME; SCHAPER, EG; Clark University; *pbergmann@clarku.edu*
The effects of granular substrate particle size and shape on sprinting in lizards
Animals are faced with diverse substrates that they must negotiate during locomotion to effectively evade predators, forage, and find mates. Granular substrates, such as sand, are extremely common in nature, and represent a locomotor challenge because their particles move when a force is exerted on them. We studied how variation in substrate particle size and shape affects locomotion in a terrestrial generalist, the Steppe Runner Lizard (*Eremias arguta*), in the context of several ecologically-relevant material properties of the substrates. In particular, we studied the packing density, angle of repose, and load-bearing capacity of the substrates. We compared a series of six substrates composed of glass beads, which varied in particle size but had a uniform shape, and six natural rock substrates (sand and gravel), which varied in both particle size and shape. We found non-linear patterns in material properties relative to particle size, with density being greatest, angle of repose lowest, and load-bearing capacity greatest at intermediate particle sizes. We also found some evidence that gravel behaves differently from sand in natural, but not glass bead substrates. This was also evident in some of the locomotor performance and kinematic variables that we studied. Maximum velocity and acceleration was greatest at intermediate particle sizes, as were stride frequencies. Duty factor tended to decrease with increasing particle size or was lowest at intermediate particle sizes. Stride length and limb angles were unaffected by particle size. Hence, substrates with very fine or very coarse particle sizes appear to represent particularly large challenges to running lizards. This may be a result of ease of displacement of small particles and an uneven running surface associated with large particles.

143.6 BERGSTROM, CA; University of Alaska Southeast; *cabergstrom@alaska.edu*

Effects of melting glaciers on estuarine fish communities

The impacts of climate change on terrestrial ecosystems may have important consequences for adjacent coastal and estuarine communities. Glaciers are retreating at high latitudes at an increasing rate, causing changes in habitat characteristics of estuaries including reduced temperature and increased turbidity. Habitat characteristics of estuaries are important to the success of young fishes using them as nurseries, affecting the abundance of later adult cohorts. Fundamental differences in habitat characteristics of estuaries adjacent to watersheds with varying degrees of glacier cover may affect their suitability as nursery and spawning grounds for marine fishes. The objectives of this study are to determine if fish community structure differs among watersheds that vary in their glacial influence and to determine if a change in glacial effluent impacts growth rate and mortality. I expect to see changes in community structure, mortality and growth rates in fishes as glacial influence on estuaries increases. I sampled juvenile and adult groundfishes for three summers from multiple estuaries in southeast Alaska that vary in their glacial influence. All fishes captured were identified to species, and their abundance and body length recorded. Individuals of two common species were tagged at each sampling event with a small colored dermal tag and released, and recaptures used to estimate growth and mortality rates among estuaries. If significant differences are found, this would indicate sensitivity to this direct and immediate symptom of a warming climate, warranting greater vigilance in the management and protection of these culturally, economically, and ecologically important coastal habitats.

P1.121 BERK, SA*; BREUNER, CW; University of Montana; *sara.berk@umconnect.umt.edu*

Glucocorticoids predict the honesty of direct benefits associated with a sexually selected trait in the mountain bluebird (Sialia currucoides).

Models of the process of sexual selection necessitate a mechanism that maintains honesty, but it is unclear if that honesty is maintained across degrading environmental conditions. We evaluated whether male coloration (a sexually selected trait) and glucocorticoids (CORT) predict the persistence of honesty across early and late season broods in the mountain bluebird, Sialia currucoides. In our study, females mated to more elaborately colored males always had larger broods, but these females were in worse body condition during second broods. In males, higher CORT predicted lower body condition during second broods, when benefits to females were lower. Furthermore, male CORT physiology was negatively associated with female body condition during both first and second broods. This suggests that while females may obtain increased fecundity from mating with more elaborate males, this may come at a cost to themselves when environmental conditions deteriorate.

P3.199 BERLIN, CG*; DORNON, MK; FELDMAN, A; GEE, JK; MORAN, CJ; ELLERBY, DJ; Wellesley College, Fairfield University; *dellerby@wellesley.edu*

Estimating the energetic costs of sunfish nesting behavior

The fitness benefits associated with parental care must be weighed against the potential costs. For example, male sunfish excavate and defend nests in which they care for eggs and newly hatched offspring, increasing their prospects of survival. The associated costs for males may however be substantial, as nesting requires a high level of physical activity and feeding opportunities are potentially limited. This may increase male mortality. Although the nesting energetic costs are assumed to be high, their magnitude is not well quantified. We have used underwater video camera arrays placed adjacent to nest sites to quantify male nesting behavior and estimate its energetic cost. Behavioral categories were identified, and time budgets established. Commonly exhibited behaviors included station holding at the nest, brief nest departures to confront potential predators, and nest fanning. Fanning may be particularly costly as it requires transfer of momentum to the water to create currents that oxygenate the eggs and remove debris while also producing counter thrust to maintain position on the nest. Fanning and station holding dominated overall time budgets, with a potential reduction in fanning behavior through the course of nesting. Video sequences were also used to quantify fish trajectories and fin beat frequencies. These data were combined with laboratory measures of swimming kinematics and metabolic rate to derive cost range estimates for each behavioral category. This indicates an average metabolic cost for nesting of approximately 20 to 40% of the sustainable aerobic maximum, a substantial cost to maintain through a multi-day nesting period.

P2.233 BERLIN, CG; CATHCART, K; DORNON, MK; FELDMAN, A; GEE, JK; MORAN, CJ; SHIN, S; ELLERBY, DJ*; Wellesley College, Fairfield University; *dellerby@wellesley.edu*

Habitat differences in bluegill sunfish swimming behavior and their relationship to intraspecific variation in performance traits

Effective locomotion is an essential component of animal survival and fitness. The demands placed on locomotor systems change markedly with respect to habitat. Habitat related differences in the physical environment, food types and locations, and exposure to predation risk potentially shift the relationship between locomotor performance and organismal fitness. Some species also show parallel variation in phenotype that may be adaptive in differentially enhancing particular aspects of performance associated with fitness within a given habitat type. For example, bluegill sunfish from open water habitats are more economical steady-state swimmers than those from the weedy, littoral, whereas littoral fish are more maneuverable than those from open water. Potential links between this performance variation and fitness can only be assessed if they are informed by locomotor performance data from the field. We have used underwater video camera arrays to quantify swimming behavior and performance of bluegill sunfish in both habitat types. When compared across similar fish size classes, times of day and season, and water temperatures there were marked habitat differences in swimming behavior. Littoral fish spent the majority of their time engaged in station holding or low-speed maneuvering controlled by the pectoral fins. In contrast, open water fish spent more time engaged in higher-speed body caudal fin (BCF) powered swimming. In both locations BCF propulsion was intermittent when present, and interspersed with periods of gliding. Open water trajectories were also associated with lower path curvature and lower turning rates. These performance analyses suggest that the performance variation quantified within this species parallels the variation in swimming behavior exhibited in the field.

P3.173 BERLOW, M*; DERRYBERRY, E; NORRIS, E; Tulane University; *mae.berlow@gmail.com*
A comparison of lethal and non-lethal sampling of avian gut microbial communities
Gut microbial communities play an essential role in the biological functions of their host. The gut microbiome mediates nutrient absorption, digests food components host enzymes are unable to, and defends the host against enteric pathogens. Gut microbiota may indirectly affect host behavior through these same mechanisms, as well as through microbial neurotransmitters and signaling peptides. Extensive research on gut microbial communities has been conducted on mammals, including humans and rats, but much less has been done in birds. Furthermore, much of the research on the effect of gut microbiota on host behavior makes use of fecal samples as a proxy for difficult to attain direct intestinal samples. Little is known however about the overlap between the microbial community of gut fauna and feces, which limits interpretability of results based on fecal samples. To address this gap in knowledge, we compare five sample types - proventriculus, small intestines, large intestines, cloacal swab, and feces - across individual zebra finches housed in constant conditions with a constant diet. We will compare diversity and community composition through amplicon-based metagenomic sequencing. Gaining insight into noninvasive sampling techniques has implications for studies of gut microbial diversity and abundance in wild bird populations. Further, reliable non-lethal sampling is necessary for temporal sampling and behavioral studies.

P1.272 BERNSTEIN, Z*; SUNDARAM, S; BALIGA, VB; MEHTA, RS; Pacific Collegiate High School, Monta Vista High School, Univ. of California, Santa Cruz, Univ. of California, Santa Cruz; *zeevbern10@gmail.com*
Assessing the convergence of feeding kinematics in labrid cleaner fishes
Convergent evolution is the process by which distantly-related taxa independently evolve similar traits, often due to similar environmental pressures. The purpose of our study is to determine whether a similar suite of traits evolves each time an ecological pattern evolves. Cleaning behavior, a mutualistic relationship wherein a species will remove and consume ectoparasites from the bodies of other organisms, has evolved numerous times in the marine teleost family Labridae (wrasses, parrotfishes, and weed whitings). While the functional morphology of feeding in some labrid cleaners has been examined, whether cleaner fish exhibit convergence in feeding behavior has yet to be analyzed. By assessing kinematic traits via phylogenetic comparative methods, we aim to understand how certain ecological processes affect the evolution of kinematic traits. For this purpose, we filmed lateral views (1000 frames/second) of 21 species of the Labridae family (10 cleaner and 11 non-cleaners) during feeding on suspended prey items. Our kinematic analysis revealed that cleaner fishes exhibit small magnitudes in the timing and displacement variables for cranial elevation, lower jaw rotation, and premaxillary jaw protrusion. When placed in a phylogenetic comparative context, labrid cleaner fishes exhibit convergent evolution in feeding behavior.

P2.128 BERTUCCI, EM*; GRAHAM, JL; NEEDHAM, KB; PEARSON, AA; GREIVES, TJ; Northern Michigan Univ., Marquette, North Dakota State Univ., Fargo; *embertuc@nmu.edu*
Early Rising Females Pair with Less Sexy Social Mates in the Dark-eyed Junco (Junco hyemalis)
Extra-pair copulations are common in socially monogamous songbirds and occur most frequently before dawn. As both sexes participate in these extra-pair behaviors, females that awaken early in the morning may be more likely to engage in extra-pair copulations. We hypothesized that males at a high risk of cuckoldry (having an early rising social mate), may alter their parental care reflecting this lack of parental certainty. The Dark-eyed Junco (*Junco hyemalis*) is a socially monogamous species, but extra-pair mating is common. The goal of this study was to assess the quality of a male's parental care in relation to the female social mate's rising time. Highly ornamented individuals often have been found to be less attentive parents, so ornamentation of males was controlled for in the analysis. We recorded female initiation of daily activity during the incubation period to assign timing phenotype, or chronotype, and quantified male feeding rate during the nestling phase. We found that males did not alter the number of feeding visits based on the female's timing phenotype or amount of white ornamentation, but females who arose earlier in the morning were found to be paired with less ornamented males. Therefore, our findings suggest that male ornamentation is not serving as an honest signal of parental quality in this population. If females are selecting mates based on ornamentation, it may not be based on relative quality of parental care. The relationship between early awakening females being mated with less ornamented males was unexpected, and future research is warranted to explore the nature of this relationship.

101.4 BETINI, G.S.*; MCADAM, A.G.; GRISWOLD, C.K.; NORRIS, D.R.; University of Guelph; *gsbetini@gmail.com*
Fitness Trade-off Between Seasons Causes Multigenerational Cycles in Phenotype and Population Size
Although seasonality is widespread and can cause fluctuations in the intensity and direction of natural selection, we have little information about the consequences of seasonal trade-offs for population dynamics. Here we exposed populations of *Drosophila melanogaster* to repeated seasonal changes in resources across 58 generations and used experimental and mathematical approaches to investigate how viability selection on body size in the non-breeding season could affect demography. We show that opposing seasonal episodes of natural selection on body size interacted with both direct and delayed density dependence to cause populations to undergo predictable multigenerational density cycles. Our results provide evidence that seasonality can set the conditions for life-history trade-offs and density-dependence, which can, in turn, interact to cause multigenerational population cycles.

131.2 BEVAN, E.M.*; COLEMEN, A.; WIBBELS, T.; SELANGI, M; University of Alabama at Birmingham, AL, Institute for Marine Mammal Studies, Gulfport, MS and Birmingham Audubon Society, AL, University of Alabama at Birmingham, Institute for Marine Mammal Studies, Gulfport, MS; *twibbels@uab.edu*

Female-biased sex ratio of immature Kemp's ridley sea turtles in the northern Gulf of Mexico

Areas of the northern Gulf of Mexico associated with major river systems have historically been noted as important foraging and developmental habitat for Kemp's ridley sea turtles. Recent research conducted in the Mississippi Sound and surrounding waters has supported this conclusion. In the current study, immature Kemp's ridley sea turtles were obtained from hook and line captures by recreational fishermen from a variety of fishing piers along the MS coast. The turtles ranged in size from approximately 20 to 45 cm (straight-line carapace length), with an average of approximately 31 cm. After capture, all turtles were transported to the Institute for Marine Mammal Studies (IMMS) in Gulfport, MS, examined by an IMMS veterinarian, and rehabilitated until suitable for release. A blood sample was taken from each turtle prior to its release. Circulating testosterone levels were determined for each turtle using a radioimmunoassay. A total of 256 immature turtles were examined in the current study. The predicted sex of each turtle was based on previous studies of juvenile Kemp's ridleys whose sex had been verified through laparoscopy. The results indicate a significant female bias (3.6F; 1.0M) in the immature portion of the Kemp's ridley population in the northern Gulf of Mexico. The female bias is similar to that reported for Kemp's ridley hatchlings produced on the primary nesting beach at Rancho Nuevo, Mexico. The occurrence of a significant female bias in the Kemp's ridley population has implications for the ecology, evolution, and conservation of this Critically Endangered sea turtle.

S10.2 BHAT, Ramray*; GLIMM, Tilmann; NEWMAN, Stuart A; BHAT, Ramray; Indian Institute of Science, Bangalore, Western Washington University, Pullman, New York Medical College; *ramray@mrdg.iisc.ernet.in*

Reaction, diffusion and adhesion by lectins in limb development: Taking it up a Notch

The avian appendicular skeleton arises from a cartilage template that is in turn prefigured by aggregations of mesenchymal cells (known as condensations) within the limb bud. The pattern that determines where condensation form, and how they are spaced apart is generated by a pair of endogenously expressed lectins, Galectin-1A and -8 and their glycoconjugate receptors. Galectin-1A (Gal-1A) is responsible for cell adhesion that leads to condensation formation whereas Gal-8 inhibits the same. Their positive regulation of each other's gene expression and opposite effect on cell aggregation has led us to construct a reaction-diffusion-adhesion model for limb patterning. What remains unclear is how this local mechanism is spatially synchronized across the morphogenetic field, i.e., the high density micromass in vitro and the digital plate in vivo. I will discuss new experimental observations that implicate the role of oscillatory expression of Notch signaling in the global entrainment of condensation formation. Integrating these findings within our theoretical framework allows us to predict the effects of Notch signaling on the pattern formation and differentiation of limb precartilage mesenchymal cells.

18.3 BIANCANI, LM*; OSBORN, KJ; CUMMINGS, MP; University of Maryland, College Park and Smithsonian National Museum of Natural History, Smithsonian National Museum of Natural History, University of Maryland, College Park; *BiancaniL@si.edu*

Unraveling the Evolutionary History of Hyperiidea (Crustacea: Amphipoda)

Amphipoda is a highly successful crustacean order with more than 8,000 described species inhabiting a wide array of marine, freshwater, and moist terrestrial environments. This ecological diversity is reflected in similarly high levels of morphological variation. The amphipods have traditionally been organized into four groups, the Hyperiidea, Gammaridea, Caprellidea, and Ingolfiellidea. Hyperiidea is an abundant and diverse group consisting of about 350 described species. No single common morphological synapomorphy unites the group. Instead, hyperiid amphipods are defined only by an exclusively pelagic existence. Previous morphological and molecular studies have led to uncertainty in the monophyly of hyperiids and the possibility of convergent evolution of pelagic lifestyles in multiple amphipod lineages. Like many midwater animals, hyperiids possess a wide range of adaptations to this unique environment, for example, a vast array of visual strategies. In order to understand these adaptations, it is necessary to study complex relationships among environment, morphology, physiology and behavior, in an evolutionary context. Such analysis hinges on an accurate phylogenetic hypothesis onto which these patterns can be mapped. Here we present preliminary results of a multi-gene phylogenetic analysis of all publicly available amphipod sequences for 3 nuclear (18S, 28S, and H3) and 2 mitochondrial loci (COI and 16S). This is the largest analysis, to date, aimed at addressing the question of hyperiid monophyly and will be used to inform taxon sampling for an ongoing transcriptome-based phylogenomic study.

P1.159 BIEDERMAN, AM*; CROCKETT, EL; Ohio University, Athens; *ab971013@ohio.edu*

Properties of Neuronal Membranes of Antarctic Notothenioids and Implications for Thermal Tolerance

Factors that limit thermal tolerance in stenothermal Antarctic notothenioids are not fully understood. In this study, properties of neuronal membranes of red-blooded *Notothenia coriiceps* and the hemoglobin-lacking icefish *Chaenocephalus aceratus* were analyzed. Myelin, synaptosomes, and mitochondria were fractionated from brain tissue using a Percoll gradient. Membrane fluidities between 0 and 40°C were quantified by fluorescence depolarization. Cholesterol levels were measured in synaptosomes and myelin, and polar lipid compositions were analyzed in myelin. Synaptosomes from *N. coriiceps* showed consistently higher membrane order than *C. aceratus* ($P<0.0001$), yet synaptosomal cholesterol-to-phospholipid ratios were similar among species. Although fluidity of myelin and mitochondria did not differ significantly between species over the measured temperature range, the thermal sensitivity of fluidity in both membranes was lower in *C. aceratus* than *N. coriiceps*. In myelin, cholesterol-to-phospholipid ratios were approximately 2-fold greater in *C. aceratus* than *N. coriiceps* ($P<0.05$). Ratios of the two major phospholipids, phosphatidylcholine (PC) and phosphatidylethanolamine (PE), differed significantly in myelin between species, with *N. coriiceps* displaying a higher PC:PE ratio ($P<0.001$). Although cholesterol levels do not account for differences in synaptosomal fluidity, cholesterol is likely to influence the thermal dependence of fluidity in myelin. Myelin enriched in lipids with known fluidizing properties appears more susceptible to fluidization with warming. Additionally, the greater perturbation in membrane fluidity with elevations in temperature in *N. coriiceps* may contribute to species differences in behavior with acute warming (see Ismailov et al., this meeting). Supported by NSF ANT 1341602.

S2.8 BINNING, Sandra A*; SHAW, Allison K; ROCHE, Dominique G; University of Neuchâtel, University of Minnesota; *sandra.binning@unine.ch*

Exercising when sick: The role of pathogens on animal activity

Studies of animal exercise and movement largely assume that individuals are healthy and performing to the best of their abilities. However, wild animals face numerous ecological challenges that can compromise their health and reduce their ability to exercise maximally. By stimulating the immune system and diverting resources away from non-essential activities, parasites and pathogens have the potential to dramatically influence the ways in which individuals allocate energy to movement. Yet, the role of parasites and disease in influencing patterns of animal activity and performance remains relatively unexplored, perhaps because animals often hide signs of sickness, and parasites tend to be small and inconspicuous to researchers. This talk will discuss how bacteria, virus and parasite infection can affect host locomotor performance and activity, including impacts on host physiology, morphology and kinematics. We will also include examples of behavioral strategies that some hosts develop to help overcome the disadvantages imposed by infection. Finally, we will highlight some recent theoretical and empirical research investigating the important role that pathogens and parasites play in driving the evolution of seasonal migration and large-scale host movement patterns more broadly.

P1.231 BIRIA, A*; MANDRE, S; VENKADESAN, M; Yale University, Brown University; *aisa.biria@yale.edu*

Stress Concentration at the Ligament-Bone Interface

Ligaments are over ten-fold softer than the bones that they attach to. Such mismatched materials, with large differences in their Young's modulus, suffer from high stress concentrations at the interface and are therefore prone to failure. Nevertheless, ligament-bone attachments are remarkably robust, and it has been suggested that the robustness is because of a transitional zone with graded mineralization, leading to intermediate material properties. We evaluate this hypothesis using analytical and computational analyses of a 2D elastic model for the interface, and find a scaling law for the optimal size of the transitional zone. Although any gradation of the Young's modulus alleviates the interfacial stress concentration, we find that some gradation profiles do so more effectively. Finally, by analyzing the maximal stress direction in the vicinity of the interface, we propose a previously unreported functional advantage for the fanned shape of ligaments near the interface, and the anisotropic nature of ligaments because of oriented collagen fibers. Collagen fibers have a higher tensile strength than the ligament matrix. Therefore, aligning these fibers parallel to the maximal stress directions is effective at preventing shear-driven failure at the interface. The fanned geometry near the interface and the anisotropic tensile strength of ligaments both achieve this function. In summary, our analyses point to three main features of biological material interfaces for improving their robustness, namely, a graded transitional zone whose size scales as a function of the interface width, a fanned geometry and anisotropic tensile strength. Preliminary evidence from published data support these predictions, and we propose future measurements of ligament-bone interfaces from different species and sizes.

32.2 BISWAS, T; BHANDAWAT, V*; RAO, S; Loyola University, New Orleans, Duke University; *tbiswas@loyno.edu*

A new biomechanical template for walking

Legged locomotion is complex: it requires precise coordination amongst multiple joints within a limb and coordination between limbs. However, many approaches to legged locomotion employ simplified approaches aimed at understanding basic principles underlying locomotion rather than the detailed dynamics of each joint and limb which may be especially useful to understand neuro-mechanical coupling and environmental influences. We will present a biomechanical template to describe "slow" walking and test our model with data from fruit flies.

P3.20 BLEVINS, B.*; CAUGHRON, J.; DAVIS, J.E.; Radford University; *bblevins6@radford.edu*

In vitro investigation of antimicrobial properties of passerine nesting materials

Birds choose their nesting materials from a wide variety of options for a range of reasons. One of these reasons may be to control the microbial environment within the nest. While there have been various studies on the relationship between nesting materials and presence of parasitic hosts, few studies have attempted to show relationships with bacterial growth. In this study we compare the antimicrobial activity of several common nesting materials (e.g., red pepper, cedar, lavender, straw, etc.). Each nesting material was ground to ensure consistency and then sterilized with UV light. Sterilized samples were added to nutrient broth containing a known quantity of *Escherichia coli*. After incubation, we performed serial dilutions and plated appropriate dilutions. We used eosin methylene blue agar plates to allow for selection and differentiation of *E. coli*. We calculated survival of *E. coli* for each nesting material and identified correlations between growth and antimicrobial activity. We will discuss initial results from our studies as well as implications for nest-structure and microbial ecology.

P3.117 BLUHER, S*; REEVE, HK; BLUHER, Sarah; Cornell University; *seb368@cornell.edu*

Modeling Individual Investment in Heterogeneous Social Groups

Individuals in cooperative groups do not always act in the group's best interests. The extent to which individuals invest in achieving group versus individual gains varies across animal societies. Polistes paper wasps are an excellent model organism for the study of social cooperation because of the range of variation in foundress association size, reproductive skew and group cohesiveness observed within a single species. In this study we seek to generate testable predictions about the strength of Polistes foundress associations given variable group sizes and relatedness of co-nesting individuals. Using a nested tug-of-war game-theoretic model, we ask how individual investment in group gains varies in a population of nests with heterogeneous group sizes. Our model results will be tested by observing foundress associations of controlled populations of Polistes exclamans nesting in enclosures. Measurements of association sizes, genetic relatedness, reproductive skew, and individual investment in nest provisioning will be compared to the model predictions.

146.3 BOARDMAN, L*; OZTEKIN, EK ; HAHN, DW; HAHN , DA; University of Florida; *lboardman@ufl.edu*

Spot the Difference: Finding a Biomarker for Irradiated Insects

With increased international trade of fresh commodities, there is a greater risk of introducing pest species to the United States. As countries move away from methyl bromide fumigation as a phytosanitary treatment to disinfest commodities, radiation provides an environmentally friendly alternative. However, unlike chemicals, radiation results in live insects arriving at a port of entry. Although these insects are sterile, and will likely die within a couple of days, there is a strong need for a simple, fast, accurate diagnostic test to confirm that these insects have been irradiated. Research shows potential applications for the use of Raman spectroscopy based detection of irradiation in honey, cells and DNA; and it has been developed for biomedical diagnosis of skin cancers. As Raman techniques result in a molecular "fingerprint", results can also point to other potential biological differences that could be exploited as irradiation biomarkers. Here, using Caribbean fruit fly, *Anastrepha suspensa*, we report on our research into whether Raman spectroscopy techniques can be used to identify irradiated insects.

P2.114 BOCK, SL*; LEMA, SC; Cal Poly, San Luis Obispo; *slema@calpoly.edu*

Temperature influences on reproductive endocrinology of the estuarine sheepshead minnow (Cyprinodon variegatus)

Temperature plays an important role in regulating reproduction in many temperate fishes. The estuarine sheepshead minnow (*Cyprinodon variegatus*) serves as a useful model for studying temperature effects on reproduction because it exhibits one of the widest thermal tolerance ranges of any fish. Here, we examined the effects of thermal environment on reproductive function in sheepshead minnows by comparing gonadosomatic index (GSI) and relative transcript levels for genes associated with gonadal steroidogenesis in sexually-mature minnows maintained at 25°C or 35°C for 14-15 days. Both females and males maintained at 35°C exhibited a smaller GSI than fish at 25°C. In addition, females at 35°C showed lower relative levels of mRNA transcripts encoding follicle-stimulating hormone receptor (*fshr*) and luteinizing hormone receptor (*lhr*) as well as cholesterol side chain cleavage enzyme (*p450scc*) and steroid acute regulatory protein (*star*). Females kept at 35°C also exhibited lower levels of mRNAs encoding two steroidogenic enzymes: ovarian aromatase (*cyp19a1a*) and 3β-hydroxysteroid dehydrogenase (*3βhsd*). Similar to females, males kept at 35°C exhibited lower relative levels of *lhr* mRNAs in the testis than males kept at 25°C. However, no difference was observed in *fshr* mRNA levels. Males also had lower testicular levels of mRNAs encoding *p450scc*, but there was no difference in *star* mRNA levels. There was no effect of temperature on mRNA abundance for *cyp19a1a* or *3βhsd* in the testis. Taken together our results imply that despite the phenomenal thermal range exhibited by *C. variegatus*, individuals experience decreased reproductive performance at 35°C even though this temperature is well within the species' thermal tolerance range.

P3.129 BODENSTEINER, B/L*; WARNER, D/A; IVERSON, J/B; MILNE-ZELMAN, C/L; MITCHELL, T/S; REFSNIDER, J/M; JANZEN, F/J; Iowa State University, Auburn University, Earlham College, Aurora University, University of Toledo , Iowa State University ; *bodenbro@iastate.edu*

Spatial and temporal variation in nest microhabitat of a widespread reptile

Species with large geographic distributions may experience a great diversity of climatic conditions. Developmental exposure to different conditions is especially pertinent in oviparous species that lack parental care. In these species, a majority of development transpires without any mitigation of the environmental conditions by the parents. Still, the maternal effect of nest-site choice, a female's choice of nest location, can affect offspring survival and phenotype. To further investigate the scope of nest-site choice, we collected nest-microhabitat characteristics (thermal environments and shade cover) in a geographically widespread vertebrate, the painted turtle (*Chrysemys picta*). Using GIS technology to identify representative locations within a designated nesting area, we collected shade cover availability and temperatures at nest depth from these locations in each of six populations (Illinois, New Mexico, Oregon, Minnesota, Idaho, and Nebraska) across multiple nesting seasons. Using a modified constant temperature equivalent model, we transform the thermal data for analysis and interpretation in the context of the relationship between developmental rate and temperature in *C. picta* nests. We hypothesized that our representative locations would encapsulate a wider range of shade and thermal conditions, whereas maternally-selected nests would be found in microhabitats that are more buffered from thermal extremes that could potentially be detrimental to offspring development. Gaining a better understanding of spatial and temporal variation in oviposition sites for species with large geographic distributions provides insights into current adaptation to local climatic conditions and could predict future patterns relative to projected global climate change.

P1.267 BOERMA, DB*; RUMMEL, AD; BREUER, KB; SCHUNK, C; SWARTZ, SM; Brown University; *david_boerma@brown.edu*

Complex Aerial Rotations Decrease Landing Impact Force in Bats

Bats roost head-under heels, requiring them to perform acrobatic maneuvers to reposition the limbs for landing. These maneuvers differ among bat species, and have diversified into at least three distinct landing styles, described as two-point, three-point, or four-point landings based on the number of limbs used to grasp the landing surface. Each style is associated with two additional features: characteristic body rotations and peak impact forces. For example, four-point landings involve simple rotations (pitch only) and are associated with relatively high peak impact forces, whereas two-point landings involve combinations of pitch, yaw, and roll to contact the ceiling with only the hindlimbs at lower peak impact forces. However, these patterns are currently described for only three species, representing two of nineteen extant families of bats. For this reason, the distribution of landing styles across extant bats is unknown, and the functional correlation between rotational complexity and impact force remains unresolved. We sampled landings across a diverse range of bat species, using high speed videography to record body rotations and a force plate to measure 3D peak impact forces. We then compared two-, three-, and four-point landings and a failed landing attempt. Our results show that landing styles involving more complex rotations consistently result in lower peak impact forces across all sampled species. This suggests that increased control over the body's rotational degrees of freedom permits more complex landing maneuvers that function to reduce impact force.

P1.122 BOERSMA, JP*; SCHWABL, HS; ENBODY, EE; KARUBIAN, JK; Washington State University, Tulane University, Tulane University; *jordan.boersma@gmail.com*

The role of androgens in evolution of male and multiple female phenotypes in a tropical passerine

Until recently female ornaments were thought be byproducts of selection for sexiness in males due to a shared autosomal genome. However, evolutionary transitions in ornamentation have occurred more often in females, often relatively rapidly, and typically in the direction of gaining ornaments. Recent work has begun to shed light on the adaptive significance of female ornaments, yet the mechanisms underlying these traits are unresolved. In males of many songbirds, seasonal increases in androgens initiate molt into ornamental plumage and onset of sexual behaviors. Female songbirds often express many of these "male typical" traits and circulate seasonally varying androgen titres. Yet, few studies have found a link between androgens and female ornaments, and the role of androgens in female organisms remains a contentious and perplexing issue. Here we explore the potential role of androgens in promoting ornamentation and sexual behaviors in a bird species with discrete female plumage morphs. White-shouldered fairy wren (Malurus alboscapulatus) males produce one plumage consisting of black with contrasting white shoulder patches (ornamented), whereas females can be cryptic brown (unornamented) or ornamented depending on the population. Unornamented females have lower baseline androgens than ornamented females, who circulate much lower titres than ornamented males. Intriguingly, male androgen titres also differ between populations, but in the opposite direction of females. We combine this dataset with behavior assays and preliminary results from an androgen supplementation experiment to address the role of androgens in phenotypic differentiation.

P1.83 BOGARDUS, RM; HATCH, K; QUINTANILLA, MA*; Brigham Young Univ., Long Island Univ., Post; *melissa.quintanilla@my.liu.edu*

Evaluating the Utility of Deuterium and Oxygen Stable Isotopes in Estimating Wood Warbler (Parulidae) Breeding Origins in the Desert Southwest

We conducted fieldwork to determine how elevation and evaporation impact feather deuterium/hydrogen ratios (δD) and oxygen-18/oxygen-16 ratios ($\delta^{18}O$) in three warbler species in the Rocky Mountains of Utah. We compared feather δD and $\delta^{18}O$ to values both from surface and rain water collected concurrent with feather growth and from δD and $\delta^{18}O$ isocline maps to determine which best predicted feather origins. Eight sites around three water bodies at three different elevations were chosen for potential evaporative distinctiveness. Primary feathers from 98 warblers were collected over the summer of 2006, after the breeding season but prior to migration. Surface and rainwater samples were collected beginning a month prior to and throughout the study period. We applied several statistical models and found no statistical difference between δD or $\delta^{18}O$ in precipitation among the different elevations. Additionally, we found no relationship between elevation change and δD or $\delta^{18}O$ in precipitation or in feathers. Differences among sites in the δD and $\delta\ ^{18}$ of surface water were not reflected in feather δD or $\delta^{18}O$ respectively. Finally, we found no relationship between the mean isotopic signature of the collected waters and that of the feathers. Long-term average precipitation values are more accurate than surface water and precipitation from the year feathers are grown, but still not very precise. Our study suggests that it may not be possible to reliably use stable isotopes alone to infer migration routes of birds whose origins are in the desert west.

12.6 BOGGETT, S; STILES, J-L; SUMMERS, AP; FUDGE, DS*; University of Guelph, University of Washington, Chapman University; *fudge@chapman.edu*

How Do Hagfishes Survive Shark Attacks?

Hagfishes are an ancient group of craniates known to thwart fish predators by deploying large volumes of gill-clogging slime when attacked. This strategy is effective against suction feeding predators, whose attempts to suck a hagfish into their mouth also pull in released slime exudate, which can set up quickly and foul the gills. But what about biting predators? Recent work has shown that hagfish slime does not prevent biting predators from making their initial attack, but instead discourages subsequent attacks. For this this strategy to work, hagfish must be able to survive the initial bite, which led us to wonder whether hagfishes possess adaptations that minimize their risk of damage from biting predators. We tested two hypotheses: 1. Hagfish skin possesses remarkable puncture resistance compared to other fish skins. 2. The lax skin, and its very loose connection to the body of the hagfish helps them avoid damage during biting attacks by allowing the musculature and viscera to slip out of the way of penetrating teeth. To test the first hypothesis, we measured puncture resistance in one species of hagfish and 19 fish species and found that, although hagfish skin is comparable to many fish skins, even those with scales, it is not exceptional in its puncture resistance. To test the loose skin hypothesis, we conducted inflation trials with two species of freshly killed hagfish and found strong evidence of a flaccid body design. We also conducted ballistic puncture tests with isolated mako shark teeth on various preparations of hagfishes and one of their closest living relatives, the sea lamprey, and found that a loose and flaccid body design does indeed prevent damage to the body relative to turgid body designs or those in which the skin is tightly adhered to the body. Our results add a new dimension to our understanding of predator defense in hagfishes.

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The Role of Corticosterone and Foraging Effort in Nomadic Migration of Red Crossbills

Spatial variation in resources presents a unique challenge to migrant birds. Red crossbills, *Loxia curvirostra*, are a nomadic finch specializing on conifer seeds that show high degrees of spatial variation but low temporal variation - generally becoming available for use in the summer. We have previously shown that crossbills prepare for spring movements by depositing fat, presumably to mitigate the risks inherent to finding unpredictably distributed resources. Here we describe how corticosterone relates to these seasonal changes and further test how manipulation of foraging effort influences behavior and physiology during the spring migratory period. We predict that increasing foraging effort will intensify or prolong migratory behavior and physiology of nomadic migrants.

P1.190 BOHN , CE*; STAAB , KL; McDaniel College ;
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Characterization of connective tissue linkages among cranial bones in largemouth bass and the functional relevance during suction feeding

Largemouth bass, *Micropterus salmoides*, use suction feeding to capture prey. Water and prey are drawn in when the skull expands creating low pressure in the mouth towards which water flows. Recent studies have shown that axial muscles power expansion of the skeletal elements within the head to produce suction. Once produced, power is transmitted from the axial muscles throughout the highly kinetic cranial skeleton. The kinematics of cranial bones in *M. salmoides* have been studied extensively and the transmission of power has been modeled using mechanical engineering theory, but the connective tissues linking these bones have been omitted from most analyses. The goal of this study was to examine the histology of functionally relevant cranial joints and skeletal elements in *M. salmoides* including the interopercular-mandibular ligament and the hyomandibulo-opercular joint. Teleosts possess a spectrum of connective tissues with varying proportions of cells to extracellular matrix (ECM) as well as components of ECM. Here we characterize the types of connective tissues found within cranial joints. Studies have shown that elastic tissues in tetrapods may aid in power transmission by acting as biological springs, so we looked at elastin as a component of these linkages. We found that the hyoid bones are composed of chondroid bone, a tissue with cartilage-like cells embedded in a mineralized matrix. It has been suggested that chondroid bone may function to conserve energy by more readily transmitting forces incurred in suction feeding events. The diversity of teleostean connective tissues may play a larger role in power transmission - and perhaps amplification - throughout the cranial skeleton during suction feeding than previously thought.

S11.3 BOK, MJ*; NILSSON, D-E; Lund Univerity;
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From Many, One: Wiring the diverse distributed visual systems of fan worms

Fan worms (Annelida: Sabellidae) posses a spectacular array of distributed compound eyes on their titular feeding tentacles. These eyes govern a startle response that allows the worms to rapidly withdraw into their tubes when threatened by looming predators. While this behavior is simple and well conserved within the family, the arrangement of their tentacular eyes is quite diverse among species, with some utilizing a single pair of large consolidated compound eyes on two tentacles while others have hundreds of smaller compound eyes or ocelli scattered all over the outsides of every tentacle. How do these two different strategies manage the same behavior, and what are their relative benefits or drawbacks? Here we present neuroanatomical and behavioral data examining the wiring of these eyes into the brain. We find that these eyes make use of neural pathways not previously implicated in visual systems, lending credence to the idea that these eyes represent an independent evolutionary elaboration unique to fan worms. Furthermore we consider possible models for the visual processing of signals from these eyes for shadow and motion detection, or perhaps even low resolution vision.

P1.273 BOLLA, V*; SUMMERS, A.P.; PAIG-TRAN, E.W.M.; California State University, Fullerton, University of Washington;
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Biomimetic Gill Raker Models Demonstrate Non-Contact Prey Retention Via Vortical Filtration in Mobulid Fishes

Mobulid fishes (manta and devil rays) are massive ram filter feeders that prey primarily on zooplankton that are routinely smaller than the apertures of their porous gill rakers. These gill rakers, supported by 5 chevron shaped arches inside the oropharyngeal cavity, consist of rows of lobes that are arranged at an acute angle to the central raphe that connects them. Pores, fissures between successive lobes, are the site of filtration. Prior studies with scaled up biomimetic gill raker models documented vortices at the filter pore that occlude the pore and may centrifugally transport particles smaller than the pore, back into the free stream that progresses posteriorly toward the esophagus. Furthermore, adjusting the lobes' leading edge shape, angle with respect to flow and surface microstructure have been shown to alter the vortex diameter. We tested actual sized models by embedding them inside a mock oropharyngeal cavity and exposing them to particle-laden fluid flow and adjusting the fluid velocity, lobe angle of attack and surface microstructure. The cavity had a simulated gill slit (ventral opening to the model) and an esophagus (opening downstream to the model) where particles were collected using a fine mesh. We used a homogenous mix of spherical artemia eggs (200-500 µm) that are heavier than water and smaller than the model pore size (1.7 mm), as particles. The simplest model (smooth) retained 4 times more particles at the esophagus while resisting half the flow compared to when the model was removed from the gill slit. These results suggest that these mobulid gill rakers use vortical filtration, a distinct mode of particle filtration among previously described systems, to concentrate particles smaller than the pore size inside the oropharyngeal cavity and to prevent the filters' clogging.

17.6 BOMPHREY, RJ*; NAKATA, T; PHILLIPS, N; WALKER, SM; Royal Veterinary College, Chiba University, Oxford University; *rbomphrey@rvc.ac.uk*

Mosquitoes Show Evidence for a New Lifting Mechanism in Insect Flight

Mosquitoes fly with a wingbeat frequency far higher than would be expected for insects of that size. We have explored the functional significance of their unorthodox flight and high aspect ratio wings. To do so, we synchronized eight high-speed cameras operating at 10 kHz and used the image sequences to reconstruct the 3D wing kinematics of *Culex quinquefasciatus* throughout the stroke cycle. These highly detailed kinematics, including wing twist, revealed wingbeat frequencies in excess of 700 Hz and remarkably low stroke amplitudes that were routinely under 40°. Such kinematics predict interesting aerodynamic consequences because the emphasis of weight support cannot be as reliant on long sweeps of the wing through the air as used by most other insects. We therefore used our kinematic data as an input for high-resolution computational fluid dynamics simulations. While the aerodynamic mechanisms for generating higher lift coefficients seen on other insects are also in effect during mosquito flight, they are of diminished significance for weight support. Instead, we find a previously undescribed mechanism for enhancing lift at the end of each half-stroke as well as a strong lifting effect from rotational drag during periods of rapid wing rotation. These mechanisms are facilitated and augmented by the geometry and kinematics of the wings.

27.4 BONKA, AN*; WIBBELS, T; HERNANDEZ, MH; NAJERA, BMZ; SARTI, L; ILLESCAS, F; PENA, LJ; BURCHFIELD, PM; UNIV. OF ALABAMA AT BIRMINGHAM, GLADYS PORTER ZOO, BROWNSVILLE, TX, COMISION NACIONAL DE AREAS NATURALES PROTEGIDAS, CIUDAD DE MEXICO, MEXICO, CONSERVACION Y DESARROLLO DE ESPACIOS NATURALES, TAMAULIPAS, MEXICO, GLADYS PORTER ZOO, BROWNSVILLE, TX; *abonka@uab.edu*

Hatchling Kemp's Ridley (Lepidochelys kempii) Sea Turtles: Nest Emergence at Their Primary Nesting Beach

Emergence from the nest represents a pivotal life history event that can significantly affect the survival of sea turtles. The type and abundance of predators, the type and availability of orientation cues, and the ambient temperature can all vary depending on the time at which hatchlings emerge. During the 2014 nesting season we utilized time-lapse cameras to monitor emergence for a sub-set of Kemp's ridley (*Lepidochelys kempii*) nests within the protective egg hatcheries (i.e. fenced off areas of the nesting beach) at Rancho Nuevo, Mexico, the primary nesting beach for this species. The thermal threshold hypothesis was not supported by our study, as time of emergence did not vary significantly over the nesting season and no correlation between date and time of emergence was detected. Our results supported the decreasing thermal gradient hypothesis, as all documented nests emerged during the decreasing phase of the daily temperature cycle, indicating this may be a cue utilized by emerging hatchling Kemp's ridleys. Hatchling emergence times may be a species and/or population specific behavior related to the ecology of specific nesting beaches. Further, the results from this study suggest it may be advantageous for programs which move nests to egg hatcheries to release hatchlings at natural emergence times in order to mimic the natural behavior which may have evolved to maximize survival.

S8.4 BONNEAUD, Camille*; RICHARDS, Adam; HERREL, Anthony; SEEBACHER, Frank; WILSON, Robbie; University of Exeter, UK, University of Colorado, Denver, National Center for Scientific Research (CNRS), France, University of Sydney, Australia, University of Queensland, Australia; *c.bonneaud@exeter.ac.uk*

Using multi-level transcriptomics and metabolic measures to investigate the trade-off between performance and immunity

Immune defense against pathogens is energetically costly and, as a result, immune activation is expected to give rise to trade-offs with other costly fitness-related functions, such as performance. Evidence for a trade-off between immunity and performance is accumulating, with infection or immune challenge reducing locomotor performance in a variety of taxa. However, we still lack a full understanding of the physiological processes mediating such trade-off, including the precise energetic requirements of competing traits and how energetic resources are allocated between them. First, we use whole-transcriptome sequencing (RNA-Seq) of muscle fibers to identify the genes and pathways associated with differences in endurance in wild Xenopus tropicalis frogs. Our results indicate that the majority of the genes and processes associated with endurance heterogeneity are involved in lipid metabolic processes and associated with muscle contraction and catabolism. Second, we investigate whether trade-offs between immunity and performance are shaped by limits on the rate of conversion of energy ingested in food into chemical energy (ATP) by oxidative metabolism rather than by the amount of food ingested in the first place. Conducting immune challenges of mosquitofish, Gambusia holbrooki, we show that immune-associated trade-offs are not likely to be shaped by limited oxidative metabolic capacities, but may instead result from limitations in the acquisition, assimilation or efficient use of resources. We discuss how studies of the molecular and physiological processes underlying immunity and performance will further our understanding of life history trade-offs.

P1.94 BONNER, ER*; SPIEGEL, EL; DAVIS, GK; Bryn Mawr College; *ebonner@brynmawr.edu*

Evolution of the Pea Aphid Photoperiod Response

The Pea Aphid, *Acyrthosiphon pisum*, exhibits a remarkable adaptive response to seasonal changes in photoperiod. In spring and summer, aphids reproduce asexually, yielding large numbers of genetically identical female offspring. The longer nights accompanying the fall induce these asexual aphids to produce sexual males and females, which mate to lay frost-resistant eggs. These eggs diapause through the cold winter months, hatch into asexually reproducing females in the spring, and the cycle continues. Pea aphid populations have been shown to exhibit latitudinal variation in this photoperiod response, presumably reflecting local adaptation to variation in the timing of the first frost (e.g., Smith and MacKay, 1990). Populations from the southern United States have been reported to exhibit attenuated photoperiod responses or to have lost the ability to produce sexuals altogether. Here we describe a previously detected difference in the photoperiod response between strains from New York and Arizona. With an eye toward understanding what underlies this difference, we also describe differences in how these strains respond to Juvenile Hormone, which has been implicated in the induction of asexual fate (e.g., Corbit and Hardie, 1985; Ishikawa et al., 2012). Additionally, our attempt to inhibit JH using Methyl Linderone failed to induce sexuals as predicted, but still holds potential for furthering our understanding of the mechanism and evolution of this polyphenism. Smith and MacKay 1990. Latitudinal variation in the photoperiodic responses of populations of pea aphid (Homoptera: Aphididae). Environmental Entomology 19: 618-624. Corbit and Hardie 1985. Entomologia Experimentalis et Applicata 38: 131-135. Ishikawa et al. 2012. Insect Mol Biol 21: 49-60

P1.25 BOOTH, AM*; HER, A; WEISSENFELS, M; JALALI, A; LAMBRECHT, DI; CHAPMAN, H; LENT, D; California State University, Fresno; *abooth@ucdavis.edu*
Caffeine's Effects on Drosophila expressing Tau Pathology
Current research indicates that caffeine administration in mammalian models expressing tau pathology (associated with Alzheimer's disease (AD)) leads to a reduction in both learning and memory deficits and neuronal damage. The effects of caffeine on tau pathology has not been studied extensively in the more basic model organism Drosophila melanogaster. Studies in Drosophila could be useful in developing models of the basic mechanisms of how caffeine could have an effect on the cognitive deficits and associated neuronal pathology in AD. Genetic tools available in Drosophila permits for controlled expression of proteins associated with AD. Experiments can be conducted with a large number of flies simultaneously, providing a high throughput model system. Here we examine spatial learning and memory, as well as longevity in Drosophila expressing human tau protein in the mushroom bodies (MBs) and ellipsoid body (EB) exposed to caffeine post-eclosion in the diet. The MBs and the EB are distinct neuropils in the brain of Drosophila that have been implicated in spatial learning and memory. Additionally, the MBs and EB have been suggested to have homologies to regions of the vertebrate brain attacked during AD (the hippocampus and striatum, respectively). Our approach thus far has focused on analyzing the effects on lifespan and on performance in visual place learning assays. Our data suggests that similar to mammalian models of caffeine and AD, caffeine exposure has a positive effect on the behavior in Drosophila expressing tau pathology. By exploring the effects of caffeine on health, spatial cognition and learning, we can better understand the broad deficits caused by tau pathology.

20.1 BOOTH, A*; ZOU, E; Nicholls State University, Thibodaux, Louisiana; *abooth@g.clemson.edu*
Impact of molt-disrupting BDE-47 on epidermal ecdysteroid signaling in the blue crab, Callinectes sapidus, in vitro
Polybrominated diphenyl ethers (PBDEs) are environmentally pervasive flame retardants that have been linked with endocrine disruption in a variety of organisms. In crustaceans, recent studies have demonstrated a molt-inhibiting effect by BDE-47, but little is known about the specific mechanism through which molt-inhibition occurs. This study examined whether the inhibitory effects arise from the disruption of hormone signaling in the epidermis using *Callinectes sapidus*. First, we partially sequenced epidermal cDNA of N-acetyl-β-glucosaminidase (NAG), a terminal enzyme in the ecdysteroid-signaling cascades. This partial cDNA sequence was then used to create primers for quantifying *NAG* gene expression. A new tissue culture technique was developed, wherein epidermal tissue and the overlying exoskeleton were immersed in a medium of a physiologically relevant osmolarity. Using this method, the inducibility of NAG by 20-hydroxyecdysone (20-HE) was assessed in vitro. Exposures to 1 µM 20-HE were found to significantly induce NAG expression. Using *NAG* gene expression as a biomarker for ecdysteroid signaling, the effects of BDE-47 were measured. *NAG* gene expression increased for exposure to a combination of 1 µM BDE-47 and 1 µM 20-HE. This trend of increasing *NAG* expression in the binary BDE-47 exposure as compared to individual exposures of these chemicals is suggestive of a synergistic effect on epidermal expression of NAG mRNA. Our findings contribute to a better understanding of the effects of PBDE contamination and mechanisms for the disruption of molting in crustaceans by BDE-47.

146.4 BOOTHBY, TC*; TAPIA, H; BROZENA, AH; PISZKIEWICZ, S; SMITH, AE; MEHTA, A; KOSHLAND, D; GOLDSTEIN, B; PIELAK, G; UNC, UC Berkeley, NCSU; *tboothby@gmail.com*
How do Tardigades Survive Extremes? Disordered Proteins as Mediators of Tardigrade Stress Tolerance
Tardigrades make up a phylum of microscopic animals renowned for their ability to survive an array of extreme environmental stresses. The molecules tardigrades make protect themselves from the harmful effects of these environmental stresses have not been elucidated. To identify mediators of tardigrade stress tolerance, we sequenced and compared transcriptomes from tardigrades that had been frozen, desiccated, or left hydrated (unstressed). We found that members of a gene family that is unique to tardigrades are upregulated during desiccation, but not freezing. We found that these genes are required for tardigrades to robustly survive desiccation, and heterologous expression of these genes in yeast or bacteria increases their desiccation tolerance by up to two orders of magnitude. Furthermore, we found that the purified protein products of these genes can protect the structural and functional integrity of desiccation sensitive proteins *in vitro*. The proteins encoded by these genes are intrinsically disordered and lack a stable three-dimensional structure in dilute solution. We found that at high concentrations these proteins interact with one another, stabilizing transient secondary structures and facilitating formation of a reticular gel matrix. Upon desiccation, this gel does not crystallize, but rather forms a vitrified, glass-like, solid both *in vivo* and *in vitro*. The vitrified state appears to be mechanistically essential for protection because disrupting the glassiness results in a loss of desiccation tolerance in both tardigrades and heterologous systems. These data identify the first functional mediators of desiccation tolerance in tardigrades and provide insight into the mechanisms used by these animals to cope with the harmful effects of desiccation.

P2.278 BORCAR, AS*; MURPHY, MP; HAND, SC; Louisiana State University, Medical Research Council Mitochondrial Biology Unit, Cambridge, UK; *shand@lsu.edu*
MitoSNO and Hypoxia Preconditioning Increase Proliferation Rate of Mammalian Cells after Acute Desiccation
Potential mechanisms for improving desiccation tolerance can be gleaned from animals that survive severe water stress in nature. Mechanisms often include accumulation of trehalose, expression of late embryogenesis abundant (LEA) proteins, and suppression of oxidative phosphorylation. We used hypoxia preconditioning to achieve metabolic adjustments in human hepatoma HepG2 cells. Cells were incubated under hypoxia (0.5% O_2) for 24 h, which promoted elevation of HIF-1α and a 62% decrease in respiration (measured under normoxia directly after hypoxia) compared to controls. HepG2 cells were transfected to express AfrLEA2, as well as a trehalose transporter to enable sugar uptake. The S-nitrosating agent MitoSNO was administered to some cells prior to removal from hypoxia to attenuate the surge of superoxide generated by mitochondria upon reoxygenation. Addition of 10 µM MitoSNO eliminated the ROS burst, as measured by oxidation of dihydroethidium. Cells were rapidly dehydrated to a residual water content of 0.225 g H_2O/g dry mass via spin-drying and then immediately rehydrated. Growth profiles across 7 days post-rehydration showed that cells receiving hypoxia preconditioning exhibited significantly greater cell proliferation than normoxic controls. Proliferation was further bolstered by the addition of MitoSNO under hypoxia prior to drying. When day 7 cell counts for normoxic controls were set to 100%, the value for hypoxia preconditioned cells was 132.6 ± 15.0% and that for hypoxia plus MitoSNO was 183.1 ± 18.3% (means ± SD, n = 6). These findings indicate that metabolic preconditioning improves biostability of mammalian cells after acute desiccation. [Supported by NSF grant IOS-1457061/IOS-1456809 and NIH grant 2-RO1-DK046270-14A1]

P2.43 BORRELLI, ST*; CHANDLER, C; State University of New York at Oswego; *sborrell@oswego.edu*
Assessment of sex chromosome influence on sexual dimorphism of the terrestrial isopod Trachelipus rathkei
The distinct chromosomes that regulate sex determination, either X and Y, or Z and W, have been observed to evolve independently in different taxa and rapidly. These sex chromosomes may often contribute specifically to the development of traits unique to each sex; for example, W chromosomes, which are specific to females, are predicted to accumulate mutations that promote female-specific fitness. The observed possibility of rapid turnover in terrestrial isopod sex chromosomes presents an ideal model system for the study of sex chromosome contributions. Genomic analysis of the sex chromosomes (Z and W) in the terrestrial isopod *Trachelipus rathkei* may provide the opportunity to better understand the rate at which evolution takes place in sex chromosomes, along with generating data that could be used to quantify the influence of sex chromosomes on sexual dimorphism. To examine the role of the Z and W chromosomes in the development of sex-specific traits, we will compare ZZ male isopods with sex-reversed ZW male isopods. These isopods, which have female genotypes but male phenotypes, were generated by implanting androgenic glands from mature males into juvenile female isopods. When these animals reach adulthood, we will measure several morphological traits and examine patterns of gene expression to test how sex chromosomes contribute to sexual dimorphism.

88.5 BORSTEIN, S.R*; MCGEE, M.D.; FORDYCE, J.A.; Department of Ecology & Evolutionary Biology, University of Tennessee, Knoxville, Institute of Ecology and Evolution, University of Bern; *sborstei@vols.utk.edu*
The evolution of diet breadth in coral reef fishes
Understanding dietary differences among taxa is a vital tool for explaining patterns like niche segregation, trophic ecology, and speciation. Here, we focus on the evolution of Diet breadth, the unique types and number of trophic resources consumed by an organism, in coral reef fishes. Coral reefs are highly complex habitats that are extremely nutrient rich, hosting an ecologically and functionally diverse group of fishes. Here we investigate patterns of diet breadth evolution in over 400 coral reef acanthomorph fish species using new ordination methods. We also investigate whether diet breadth evolution is tightly coupled to functional trait evolution, using seven key ecomorphological traits. Our results indicate that while species may occupy similar areas of diet breadth space, they may significantly vary in morphospace occupation.

93.6 BORTOLINI, J.L.; BAUER, R.T.*; Universidad Nacional Autónoma de México, University of Louisiana, Lafayette; *rtbauer@louisiana.edu*
Persistence of reduced androgenic glands after protandric sex change is a possible basis for simultaneous hermaphroditism in the marine shrimp Lysmata wurdemanni
The caridean shrimp *Lysmata wurdemanni* is a protandric simultaneous hermaphrodite in which individuals go through a male phase before changing sex to female-phase simultaneous hermaphrodites. The latter have an externally female phenotype but retain a reduced male reproductive system and complete male and female reproductive function and behavior. Previously published studies reported that the androgenic glands, whose hormones stimulate development of male characteristics in decapod crustaceans, are absent in the female phase of purely protandric species. We tested the hypothesis of androgenic gland absence in simultaneous hermaphrodites of *L. wurdemanni* by dissection and histology on the ejaculatory ducts. These glands were observed in the simultaneous hermaphrodites although in a variably degraded form. Androgenic glands of *L. wurdemanni* male-phase individuals are compact and replete with well-developed cells with large, deeply staining nuclei, as in males of gonochoric and protandric species. The androgenic glands of simultaneous hermaphrodites were more reticulate in structure due to cell degeneration, resulting in vacuolization of the glands, but all possessed from numerous to at least some possibly functional cells. The greatest degeneration of the androgenic glands was observed in the largest (oldest) hermaphrodites. However, the ovotestes of all simultaneous hermaphrodites retained a small testicular portion with well-developed ejaculatory ducts containing sperm. Our results support but do not completely test the hypothesis that the reduced androgenic glands of *L. wurdemanni* female-phase simultaneous hermaphrodites accounts for their maintenance of male reproductive function after sex change.

P3.73 BOSTWICK, CJ*; YANG, Q; KOHN, AB; HAWKINS, RD; MOROZ, LL; University of Florida, Columbia University; *cbostwick87@gmail.com*
Single neuron RNA-Seq reveals differential expression in neurons regulating the defensive withdrawal reflexes of Aplysia californica
Aplysia californica is a valuable model organism for the genomic and transcriptomic analysis of learning and memory. The neural circuits controlling the defensive withdrawal reflexes of this organism have been analyzed extensively, to the level of individual, functionally identified neurons. These circuits are capable of several forms of learning, including sensitization, habituation, and classical conditioning. We utilized RNA-seq to profile individual sensory and motor neurons known to control both the tail-withdrawal reflex (TWR) and siphon/gill-withdrawal reflex (S/GWR). We discovered a multitude of transcripts to be differentially expressed between the pleural ventrocaudal (VC) sensory neurons of the TWR and the abdominal LE sensory neurons of the S/GWR. These included multiple transcripts, including several uncharacterized transcripts (among others). We also analyzed differential expression between the LFs motor neurons contributing to siphon withdrawal of the S/GWR and the L7 motor neurons contributing to the gill withdrawal component of the S/GWR. Several transcripts were found to be differentially expressed suggesting differential regulation of these genes. These differentially expressed transcripts may help us to identify functionally similar neurons and their expression profiles as they are involved in defensive withdrawal reflexes and produce their repertoire of signaling molecules to be utilized by each circuit.

P1.89 BOUCHARD, SS; Otterbein University; *sbouchard@otterbein.edu*

Silver Spoon Effect in Larval Anurans

The silver spoon hypothesis predicts that favorable conditions early in life continue to provide an advantage through adulthood, even if conditions worsen. Although a variety of taxa exhibit this effect, few studies have involved amphibians. We tested the silver spoon hypothesis in the American Toad, *Anaxyrus americanus*, by rearing larvae in the lab in low density, high resource tanks (n = 14) and high density, low resource tanks (n = 14). Once larvae reached a standard size of approximately 2.3 cm and 0.2 g, we selected three size-matched larvae from each tank and transferred them to a second tank containing either a high food level (*ad libitum*, n = 7) or a low food level comparable to that experienced in the initial high density tanks (n = 7). We measured change in mass after one week and then toadlet snout-vent length and mass once metamorphosis was complete. Before transfer, larvae in low density tanks grew significantly faster than those in high density tanks and reached the standard size three days sooner. As expected, those larvae transferred to the high food level grew significantly faster than those transferred to the low food level. However, within both food levels, larvae initially reared at the low density grew faster than those reared at the high density, despite having identical food resources post-transfer. Larvae initially reared at low density also metamorphosed into significantly larger toadlets. This supports a silver spoon effect in that larvae reared under favorable conditions early in development acquired a growth advantage that persisted through metamorphosis. Future studies should consider lasting effects later in life.

P3.187 BOWER, ED*; TAMONE, SL; University of Alaska Southeast; *sltamone@alaska.edu*

Morphology and Reproductive physiology of the Northern spot shrimpPandalus platyceros from Alaska

The Northern spot prawn (*Pandalus platyceros*) is a commercially important shrimp species in Southeast Alaska that has an interesting life history which presents challenges for its effective management. *P. platyceros* is protandric and demonstrates sequential hermaphroditism. As this shrimp matures and grows, it transforms from a small functional male to a much larger functional female. During its life history, the male shrimp undergoes at least one transitional phase during which it is not known if it functions as a male or a female. Our study objectives were to identify each life history stage through examination of the 2nd pair of pleopods and determine the life history specific size range of *P. platyceros*. A second goal was to investigate the reproductive biology of female shrimp to determine whether females produced multiple clutches or if they are semelparous. We measured the gonadosomatic index (GSI) of a subset of the collected females. Male (n=46), transitional (n=25), ovigerous females (101), and non-ovigerous females (n=17) were collected in Southeast Alaska in February and maintained at the University of Alaska Southeast marine laboratory in flow-through seawater. Male carapace length (CL; 34.6 ± 4.4 mm) was less than transitionals (40.3 ± 3.2 mm) and females (45.3 ± 4.1 mm). Ovigerous females hatched beginning in late April and hatching times averaged 2 weeks. Females molted after hatching but did not mate in the lab. Non-ovigerous females demonstrated a greater GSI than the ovigerous females (1.75 ± 1.5 verses 0.62 ± 0.145) and only three ovigerous females extruded eggs after molting. These observations support female *P. platyceros* being able to develop multiple clutches over their lifetime. Our studies show that the reproductive biology of this cold water species is complex and that females may produce clutches every other year.

P3.72 BOYKIN, J.*; TAMVACAKIS, A. N.; KATZ, P. S.; Georgia State University; *jboykin4@gsu.edu*

Single-Cell Transcriptomics of Homologous Peptidergic Neurons in Nudipleura Sea Slugs Reveals Species Differences in Neuromodulatory and Developmental Gene Expression

Single-cell RNA sequencing has been used to differentiate neuronal classes in mammalian brains. In Nudipleura molluscs (Gastropoda, Heterobranchia), individual neurons are readily identifiable by characteristic neuroanatomical and neurochemical features. We performed a single-neuron transcriptomic study to determine the extent to which identified neurons can be recognized by their gene expression patterns, and to which they may differ from homologous neurons in other species. We compared the Cerebral Neuron 2 (C2) homologs in three Nudipleura molluscan species. Two of the species, *Tritonia diomedea* and *Pleurobranchaea californica*, exhibit a swim behavior consisting of dorsal-ventral body flexions; C2 is a component of the central pattern generator for this rhythmic behavior. The third species, *Hermissenda crassicornis*, swims with alternating left-right body flexions. Differential expression analysis using Swiss-Prot annotated single-neuron transcriptomes (five replicates per target) identified nearly five thousand orthologous genes between *Tritonia* and *Hermissenda* C2 homologs. Expression patterns between species replicates showed greater commonality than among interspecies homologs. Of the 4,789 orthologous genes identified, 968 (20%) were differentially expressed. Of these, several are defined to be high-expressing neuromodulatory genes related to neuronal excitation and synaptic transmission. Furthermore, transcription factors related to nervous system development showed significant expression differences. We are investigating the implications that the unique single-neuron transcriptomic profiles have on nervous system function, particularly with respect to the swim circuit and neural development.

P2.259 BOYLAN, RB*; GRANDY, E; DAVIS, JE; Radford University; *rboylan1@radford.edu*

Effects of VAAM (Vespa Amino Acid Mixture) in combination with potassium cyanide in the house fly (Musca domestic)

Potassium cyanide inhibits the function of the enzyme cytochrome c oxidase (aa_3) in the fourth complex of the electron transport chain within the membrane of mitochondria. The binding of cyanide to aa_3 prevents transport of electrons from the cytochrome c to oxygen, inhibiting the electron transport chain and preventing the cell from aerobically produce ATP. At the organismic level this causes mass death of cells within the body and leads to brain and heart failure within minutes, also known as histotoxic hypoxia. Recent studies in our laboratory and others have suggested that cyanide poisoning in cell cultures may be inhibited by simultaneous exposure to VAAM. VAAM, or vespa amino acid mixture, is a compound produced by Japanese giant hornets which has been shown to cause an increase in the production of ATP within exposed cells and an increase in overall endurance in treated house flies. Interestingly, VAAM exposure in isolation also leads to increased apoptosis and an overall increase in mortality. The experiment described here is an extension of the results gathered from work on cell cultures, in which we studied the effects of exposure to VAAM and potassium cyanide on mortality and endurance in house flies (*Musca domestic*.) House flies were dosed with a combination of potassium cyanide and VAAM in various time schedules, and their lifespans and endurance on swim tasks were compared to those of flies that were exposed to either cyanide or VAAM or neither (control.) Here we will discuss implications of our findings both for understanding the mechanism of action of VAAM and in interaction with mitochondrial membrane dynamics.

138.3 BOYLE, KS*; COUILLAUD, P; HERREL, A; Univ. of West Florida, MNHN, Paris, MNHN/CNRS, Paris; *kellyboyle.info@gmail.com*

Shape variation of the neurocranium and anterior vertebrae related to the auditory system in piranhas and pacus (Otophysi: Serrasalmidae)

Otophysan fishes possess a number of unique morphological features associated with enhanced hearing. These features include a Weberian apparatus that is composed of three pairs of ossicles that link the swim bladder to the inner ear, modifications of the associated first four vertebrae, and a well-developed lagena. In addition, within the otophysan clade, characiform fishes possess a foramen in the prootic that is open to the utricle and may have an auditory function. Auditory cues are likely to have influenced the evolutionary morphology of fishes in the family Serrasalmidae (piranhas, pacus, tambaqui). These fishes have a variety of feeding ecologies and behaviors which include fish predation, scale and fin feeding, frugivory, and herbivory of aquatic macrophytes. Sound may be an important cue for finding food resources in some species. In addition, several rheophilic species occur in rapids of rivers, which are high noise environments. We are examining shape of the neurocranium, lagenar capsule (basioccipital and exoccipital), cavum sinus imparis, prootic foramen, and vertebrae (1-4) of 20 species of serrasalmid fishes obtained from microCT scans. Preliminary observations indicate wide variation in the relative size of lagenar capsules and prootic foramen shape. 3D Geometric morphometrics is being used to quantify shape variation among taxa. This study is expected to determine the degree of covariation of these features and reveal any patterns associated with phylogeny and ecology.

137.4 BRACISZEWSKI, AR*; GERMAN, DP; Univ. of California, Irvine; *alyssarb@uci.edu*

Relatedness and differential disease resistance in eastern Pacific Haliotids

Many marine host-pathogen systems are poorly understood, and even less is known about how global climate change will affect the mechanisms of these systems. In the abalone and *Rickettsiales*-like organism (RLO) system, the RLO infects abalone digestive tissues and leads to extreme starvation and a characteristic "withering" of the gastropod foot. First identified in black abalone in California after an El Niño event, the withering syndrome-causing RLO (WS-RLO) has been seen in various sites around the world, and has been found in at least low levels in all abalone species examined, yet not all express WS[1]. Some abalone species appear to be highly resistant to the disease, unless held at extremely high temperatures. This suggests that the resistant species possess some physiological resistance to the effects of high temperature. Our goal is to develop a detailed understanding of the abalone digestive system and the mechanisms for differential resistance across the *Haliotis* (abalone) genus. In order to clarify differential susceptibility in geographically neighboring species (such as the highly susceptible red abalone *H. rufescens* and relatively resistant green abalone *H. fulgens*), we are creating a robust phylogeny of *Haliotis* to determine whether certain branches are more susceptible to WS. This phylogenetic tree was created using concatenated data from two multiple mitochondrial (*16s* and *cyt*b) and three nuclear genes (*h3* and *its1/2*), and will result in the most robust phylogeny of eastern Pacific Haliotids to date. Interestingly, the two most resistant species, *H. fulgens* and *H. corrugata*, are sister taxa that form a clade separate from the other California taxa. Ref:[1]Crosson, L.M. et al. (2014) Abalone withering syndrome: distribution, impacts, current diagnostic methods and new findings. *Diseases of Aquatic Organisms* **108**, 261-270.

P2.102 BRANDES, S*; MCDOWELL, KP; PETERS, MC; FOLTS, SL; DAVIS, JE; Radford University; *sbrandes@radford.edu*

Does nestling quality vary between urban and rural habitats in eastern bluebirds (Sialia sialis)?

Urbanization causes habitat fragmentation that can impact many species of wildlife. Urban habitats present animals with different types and degrees of environmental stressors, including but not limited to, light pollution, noise, resource competition, and predation risk. Eastern bluebirds *(Sialia sialis)* breed in both of these habitat types, and these stressors may impact nestlings being reared in these different settings. Here we studied whether bluebird nestling quality, as measured by body condition and heat shock protein levels, varied by habitat type. Heat shock proteins are produced when organisms are exposed to stressors such as inclement weather or physical injury, and serve to stabilize proteins during folding. We measured 11-day old nestling's size and weight, and collected blood samples to measure the heat shock protein content. Data were collected from 6 nests in a rural setting and 8 nests in an urban setting. Data analysis is ongoing. We expect to find urban nestlings to have higher heat shock protein levels and lower body condition than rural ones. These findings would suggest that urbanization is having a negative impact on eastern bluebird nestling health, potentially impacting the continuance of these populations.

46.7 BRANDLEY, N*; CAVES, E; Colorado College, Duke University; *nicholas.brandley@coloradocollege.edu*

Visual acuity in birds: Effects of behavior, ecology, and morphology

The use of the phrase "eagle eye" illustrates the widespread belief that birds have sharp spatial vision. Although some birds of prey do show visual acuity measurements finer than humans, these studies are limited to just a few species. In order to understand the visual capabilities of birds in general, we conducted a literature review of avian visual acuity (n = 88 unique species). We find that the median visual acuity in birds is approximately 10 cycles per degree, or around six times coarser than that of humans. Using phylogenetic generalized least squares, we examine how several behavioral (activity pattern, diet), ecological (habitat), and morphological (body and eye size) factors correlate with variation in avian visual acuity. This study helps explain how visual abilities may (or may not) be adapted to an animal's needs. Additionally, by exploring how ecology and morphology influence visual acuity, we uncover underlying relationships that allow researchers to predict the visual acuity of their study species when formal measurements may be lacking.

66.7 BRANDT, R*; WARNER, DA; Auburn University; *rbrandt@usp.br*

Maternal and genetic additive effects on sprint speeds and morphological traits variation of offspring lizards

Response to selection require traits to be heritable, but maternal effects, or the effects of parent's phenotypes on their offspring phenotypes, can also influence the evolutionary process. Therefore, for a complete understanding of evolution, it is essential to understand how both genetic additive and maternal effects contribute to phenotypic variation. For example several studies of squamate reptiles present high broad-sense heritability (i.e., total genetic variation/ phenotypic variation) in performance-related and morphological traits. Nevertheless, this high heritabilities could be attributable to maternal effects since broad-sense estimations of heritability includes maternal effects in addition to common environmental effects. We took advantage of a seminatural breeding experiment and measured sprint speeds and several morphological traits in an Australian agamid lizard (*Amphibolurus muricatus*) parents and offsprings to understand the role of maternal and additive genetic effects in driving variation in offspring traits. Our data was collected when both parent and offspring were still hatchlings. Maternal and paternal identity of offspring were established and we then used animal models in order to partition phenotypic variance between maternal and additive genetic effects in traits that are believed to be under selection in many lizard species. We used a half-sibs design, which allowed us to better partition variance between additive genetic and maternal effects in comparison with full-sibs design and traditional parent-offspring regressions. We compare our results to published reports of heritabilities for squamates and other animals, and discuss the implications of our findings as well as future prospectives for research.

P3.185 BRASHER, AL*; ZHANG, Y; KAVAZIS, AN; HOOD, WR; Auburn University; *alb0081@auburn.edu*

Does relative activity prior to breeding improve mitochondrial function and oxidative damage following a reproductive event?

Our understanding of the physiological responses to stress of wild animals is often based on studies where data is collected over a short period of time. Although many fundamental insights have been gained from this approach, this design often ignores the fact that each individual has experienced a unique set of sequential events that may have altered its physiology. These carry-over effects may explain much of the variation in performance and fitness found among individuals in wild populations. Moderate activity, or exercise, is associated with a plethora of benefits at the cellular level including improved mitochondrial function. For this study, we asked if the beneficial effects of exercise on mitochondria carry over to reproduction, improving the impact that reproduction has on mitochondrial capacity and function. We used the outbred IRC mouse as a model. Half of the mice were given access to a running wheel and half were not. The impact of running on mitochondrial function was then quantified after 1 month in half of the animals, with equal numbers collected from each group. The remaining animals were then bred so that the impact of running prior to breeding could be quantified. Relative to mice that did not have access to a running wheel, mice that ran demonstrated significantly higher total leg muscle mass ($p < 0.05$), a trend toward lower leg muscle ROS production ($p = 0.07$) and significantly greater respiratory function ($p < 0.05$). These results support prior findings that suggest exercise improves mitochondrial performance and thus, provides an exciting framework for our ultimate prediction that the positive mitochondrial effects of exercise will persist following a future reproductive event. These findings will be presented.

10.6 BREDLAU, JP*; KESTER, KM; Virginia Commonwealth University; *bredlauj@vcu.edu*

Building a Phylogeny of Parasitic Wasps in the Genus, Cotesia, Based on Species-specific Courtship Songs

Acoustic signals play an important role in premating isolation based on sexual selection within many taxa. Evidence for several genera of parasitic wasps within the Braconidae demonstrates that males produce a characteristic courtship song used by females to identify conspecifics. In *Cotesia* (Braconidae), courtship songs are generated by wing fanning and repetitive pulses in stereotypical patterns. Our objectives were to determine if male courtship songs within *Cotesia* are species specific, and therefore could function in premating isolation, and if so, which components differed. We compared songs among 12 of ca. 80 described *Cotesia* species in North America, including ten species that have not been recorded previously. Pattern, frequency, and duration of song elements were analyzed using Raven Pro. Principal component analysis was used to convert the seven elements characterized into uncorrelated components used in a hierarchical cluster analysis and to group species by similarity of song structure. Songs among species varied significantly in duration of repeating pulse and buzz elements and in fundamental frequency. Songs within species were structurally conserved. The first three principal components explained 85% of the variance of song elements. The dendrogram produced by the cluster analysis of principal components generally mirrored the most recent proposed molecular phylogeny for *Cotesia* spp. by Michel-Salzat & Whitfield (2004), indicating the potential for using courtship songs as a predictor of genetic relatedness. Courtship song analysis may also aid in identifying closely related cryptic species with sympatric distributions, and provide insight into the evolution of this highly diverse and agriculturally important taxon.

114.3 BRESSMAN, NB*; BUSER, T; SUMMERS, D; GIBB, AC; SUMMERS, A; Wake Forest University, Oregon State University, Friday Harbor Laboratories, University of Washington, Northern Arizona University, Friday Harbor Laboratories, University of Washington; *bresnr16@wfu.edu*

Intertidal sculpins aren't fat, they're big boned! Influence of habitat on pectoral ossification in Cottoid fishes

Intertidal fishes experience greater physical forces from currents and waves than subtidal fishes. In addition, some intertidal fishes may move over land from one pool to another; walking on land will increase the load that the fins will bear due to the forces of gravity. We hypothesized that intertidal sculpins (superfamily Cottoidea) have more ossification in their pectoral girdles and fins, relative to subtidal species. Using µCT whole-body scans of 35 sculpin species and calibration phantoms (hydroxyapatite-based objects of known density), we measured mineralization of the radials, cleithrum, and individual pectoral fin rays. From these analyses we have ascertained that benthic sculpins have asymmetrically ossified hemitrichia (paired halves of fin rays): the medial hemitrich is more ossified than the lateral hemitrich. This may be an adaptation to strengthen the region of the pectoral fin that typically is in contact with the substrate. In addition, intertidal and shallow-water sculpins have more heavily ossified pectoral girdles than do deep-water subtidal sculpins. In fact, ossification decreases linearly with habitat depth ($R = -0.522$) and the absolute number of pectoral fin rays also increases with habitat depth ($R = 0.518$). We suggest that the heavily ossified pectoral bones of intertidal and shallow-water sculpins may provide a safety factor that protects them them from the greater forces they experience in the wave-swept near-shore environment and on land.

P1.92 BRETZ, KJ*; BONISOLI-ALQUATI, A; MOUSSEAU, TM; Univ. of South Carolina, Columbia, Louisiana State University, Baton Rouge ; *kbretz@email.sc.edu*

Effects of Radioactive Contamination in Chernobyl, Ukraine and Fukushima, Japan on the Developmental Instability of Butterfly Species

The long-term effects of radioactive exposure from nuclear accidents on environments are virtually unknown and there is a need for assessments of radiation effects on living organisms. Past studies have found an increased frequency of developmental abnormalities in butterflies exposed to various levels of radioactive contamination. We collected butterfly species from clean and radiation-contaminated sites around Chernobyl, Ukraine and Fukushima, Japan. Morphometric analyses were used to identify variation in wing vein patterns, with fluctuating asymmetry (FA), the variation between the left and right wings, as our primary measurement of developmental instability related to the mutagenic effects of radiation. We analyzed the size and shape of the wings from each species as indexed by centroid size and Procrustes distance. Our preliminary results indicate that there is no significant relationship between FA and background radiation, however there was significant variation in wing centroid size between clean and irradiated sites, with butterflies exposed to long-term radiation having an overall smaller size. The results for Procrustes distance were predominately inconclusive, with varying results for different species and minimal levels of significance. This project is set to continue for several more years in order to create a stronger longitudinal study.

61.5 BREUNER, CW*; BERK, SA; The University of Montana; *creagh.breuner@umontana.edu*

Testing the Fitness Effects of Glucocorticoids Within a Resource Framework

There are three main hypotheses regarding the effects of glucocorticoids on fitness. The CORT-tradeoff hypothesis suggests that elevated CORT reallocates energy away from non-essential processes, such as reproduction, and towards survival. The CORT-adaptation hypothesis suggests that elevated CORT can enhance reproduction. The CORT-fitness hypothesis posits that since CORT is elevated when environmental or internal conditions deteriorate, elevated CORT will be associated with a decline in fitness overall (likely declines in both survival and reproduction). Tests of these hypotheses have produced highly variable results. We propose that the discrepancy in results may be due to variation in resource availability. In free-living animals, trade-offs may be masked by high resource availability in good years, but evident in poor years. Current literature testing between these hypotheses rarely incorporates metrics of resource availability. In 1986 Van Noordwijk and de Jong proposed the acquisition/allocation model to explain positive vs. negative correlations between reproduction and survival across individuals. Their model identifies resources as critical to evaluating individual allocation strategies (favoring reproduction vs survival), and therefore provides the ideal model for testing across the three CORT hypotheses. Here we 1) evaluate current literature on CORT and fitness in light of resource availability and 2) suggest methods for testing the three hypotheses using Van Noordwijk and de Jong's framework.

139.2 BREVES, JP*; DUFFY, TA; EINARSDOTTIR, IE; BJöRNSSON, BT; MCCORMICK, SD; Skidmore Coll., Northeastern Univ., Univ. of Gothenburg, Univ. of Gothenburg, USGS, Conte Anadromous Fish Res. Cen.; *jbreves@skidmore.edu*

In vivo effects of 17α-ethinylestradiol, 17β-estradiol and 4-nonylphenol on hepatic insulin-like growth-factor binding protein (igfbp) mRNA levels in Atlantic salmon

Feminizing endocrine disrupting compounds (EDCs) affect the growth and development of teleosts. The growth hormone (Gh)/insulin-like growth-factor (Igf) system is sensitive to estrogenic compounds and mediates some of the physiological consequences of EDC exposure. Nonetheless, there is no grasp on whether modulators of Igf activity, namely Igf binding proteins (Igfbps), are impacted by EDCs. We investigated two early life-history stages (juveniles and smolts) of Atlantic salmon (*Salmo salar*) and characterized how the Gh/Igf/Igfbp system responded to waterborne 17α-ethinylestradiol (EE_2), 17β-estradiol (E_2) and 4-nonylphenol (NP). In juveniles (~0.5 g) exposed to EE_2 and NP for 21 days, hepatic *vitellogenin* (*vtg*) was induced while *estrogen receptor α* (*erα*), *gh receptor* (*ghr*), *igf1* and *igf2* mRNA levels were diminished. EE_2 and NP reduced hepatic *igfbp1b1*, *-2a*, *-2b1*, *-4*, *-5b2* and *-6b1*, and stimulated *igfbp5a*. In smolts, exposure to EE_2 for 4 days diminished plasma Gh and Igf1 levels in parallel with reductions in hepatic *ghr* and *igf1*. Hepatic *vtg* was induced following exposure to EE_2, E_2 and NP, while *erα* only responded to EE_2 and E_2. EE_2 and E_2 diminished hepatic *igfbp1b1*, *-4* and *-6b1*, and stimulated *igfbp5a*. We conclude that hepatic *igfbps* respond (directly and/or indirectly) to environmental estrogens during two key life-history stages of Atlantic salmon, and thus may modulate the growth and development of exposed individuals.

75.1 BROCCO FRENCH, KI*; ALLEN, JD; College of William and Mary; *Kibroccofrench@email.wm.edu*

Density dependent and size specific cannibalism among juvenile echinoderms

Benthic marine invertebrates recruit unevenly. During dense settlement years, cannibalism may contribute significantly to juvenile mortality but may also function as a constructive process by promoting the growth of individuals who cannibalize. As early as 4 days post-metamorphosis we observed frequent cannibalism among juveniles of the sea star *Asterias forbesi*. To determine if cannibalism was density dependent, we placed 2-3 week old juvenile sea stars at varying densities in 200 mL beakers. After one week, mortality rates of isolated juveniles were 10% while mortality rates at densities of 2, 10 and 20 juveniles per beaker were 10%, 73% and 90% respectively. We then conducted trials with juvenile densities matched to field observations made during moderate recruitment years. Control juveniles experienced 5 ± 3.2% mortality, while juveniles allowed to cannibalize each other experienced 20 ± 2.7% mortality. We then created pairs of juveniles with differences in disk diameters ranging from 25-775 µm. We found that cannibalism was size specific: larger juveniles were more likely to be cannibalistic than smaller juveniles. We also found that the greater the size difference between juvenile pairs, the more likely they were to cannibalize. Finally, we found that cannibalism occurred even when juvenile mussels were provided as an alternative food source, suggesting that cannibalistic behavior is not limited to years when other food sources are limiting. To our knowledge these are the first experiments showing that juvenile cannibalism in *A. forbesi* is density dependent, size specific, and occurs at natural densities.

S8.11 BRONIKOWSKI, Anne M.*; GANGLOFF, Eric J.; SCHWARTZ, Tonia S.; Iowa State University, Auburn University; *abroniko@iastate.edu*

Life history phenotypes, metabolic performance and fitness in garter snakes with divergent life histories

As a pace-setter for physiological processes, variation in metabolic rate can determine the shape of energetic trade-offs and thereby be an important factor that facilitates variation in life-history traits. In turn, such variation in metabolic performance and life-histories can have profound consequences for fitness. Thus, the extent to which metabolic variation is due to phenotypic plasticity or fixed genetic differences among individuals or populations is likely to be shaped by natural selection. We synthesize our studies on metabolic rate variation in garter snakes (*Thamnophis elegans*) exhibiting contrasting life-history strategies - either growing fast and reproducing early versus growing slowly and delaying maturation - that have been measured in a variety of age classes and developmental backgrounds. With this synthesis of numerous datasets, we are able to ascertain the relative influences of developmental plasticity and local adaptation in shaping thermal reaction norms of metabolic rate. Furthermore, we provide new data on the association of fixed metabolic differences with mitochondrial haplotype divergences between the ecotypes. Finally, we assess the fitness consequences of this interrelated metabolic rate variation and life-history variation for these snakes.

P2.144 BROOKS, C.A.C.*; MCGUIRE, L.P.; BOYLES, J.G.; Southern Illinois University, Texas Tech University; *cbrooks@siu.edu*

Effects of Artificial Lighting on Bat Activity in Forested and Agricultural Habitats

Bats are economically important predators of agricultural pests and excluding them from agricultural areas can have devastating effects on crop production. Artificial lighting is a growing conservation concern and is known to disrupt many aspects of bat behavior including commuting and foraging, forcing bats to avoid areas they normally occupy or use them in different ways. Further, artificial light likely modifies more effects of natural moonlight on bat behavior. Light emitting diodes (LED) are becoming more common as a light source because they are energy efficient and LEDs have been found to have effects on bat behavior comparable to other lighting types. In this study, we assessed bat activity levels as they relate to artificially lit and unlit conditions across several lunar cycles. We used bat detectors (Anabat) to compare foraging activity of two bat communities in different habitats (agriculture and forest) in the presence and absence of artificial light (accomplished with 30W LED lights 3.5 m off the ground). Bat activity was generally higher in the agricultural habitat. The interaction between artificial light and moonlight was also stronger at agricultural sites. Our results indicate LED lighting does affect bat activity but this effect is variable. The extent and direction of this influence is dependent upon the local habitat. Artificial lighting around agricultural fields could alter bat activity resulting in a change in crop quality, subsequently influencing their economic value.

P1.61 BROTHERS, CJ*; SMITH, KE; AMSLER, MO; ARONSON, RB; SINGH, H; MCCLINTOCK, JB; Univ. of Alabama at Birmingham, Florida Institute of Technology, Woods Hole Oceanographic Institution; *brotce@uab.edu*

Sea Urchin Covering Behavior as a Possible Response to Deep-Water Antarctic Predatory King Crabs

Sea urchins (Echinoidea) from shallow, well-lit environments are commonly observed lifting materials from the surrounding substrate onto their aboral surfaces. This covering behavior may provide a variety of benefits, including protection from ultraviolet radiation and predator avoidance. However, covering behavior in deep-water sea urchins is rarely observed, and its functional significance remains speculative. Using SeaSled, a towed-camera vehicle, we conducted photo-transects off Anvers Island and in Marguerite Bay along the western Antarctic Peninsula (390-2100 m depth). We recorded the number of sea urchins, incidence of covering behavior, types and availability of covering materials, potential predators of sea urchins, and potential prey items for predators. The regular sea urchin *Sterechinus* spp. was observed at all depths, and the percentage of individuals exhibiting covering behavior increased with depth. There was a significant positive correlation between the incidence of covering behavior and the density of king crabs (Anomura: Lithodidae), crushing predators that may be extending their range up the Antarctic continental slope as a result of warming ocean temperatures. In contrast, covering behavior was not positively correlated with the availability of covering materials, the densities of non-crab predators, the total density of predators, or the availability of prey. Our results suggest that covering in deep-water sea urchins is a behavioral response to reduce predation by king crabs.

28.8 BROTHERS, CJ*; VAN DER POL, WJ; MORROW, CD; HAKIM, JA; KOO, H; MCCLINTOCK, JB; Univ. of Alabama at Birmingham; *brotce@uab.edu*

Climate Warming Alters Predicted Microbiome Functionality in a Model Sea Urchin

The microbiome of the sea urchin *Lytechinus variegatus* plays a crucial role in maintaining its digestive health and innate immunity. This sea urchin is an ecologically important herbivore associated with seagrass beds where it is seasonally exposed to temperatures near its upper thermal limit. Accordingly, it is important to evaluate whether predicted near-future seawater temperatures resulting from climate change will impact the community structure and predicted functional attributes of the microbiota associated with the tissues of *L. variegatus*. Sea urchins were exposed to current and near-future seawater temperature treatments (26 and 30°C; n=5 per treatment) for 90 days while being fed a diet of the seagrass *Thalassia testudinum*. After 90 days, sea urchins were sacrificed and samples from both temperature treatments (seawater, food, intestinal tract, coelomic fluid, digested food, and feces) were collected. The metacommunity 16S rRNA genes (V4 region) were sequenced using the Illumina MiSeq™ platform, and community composition and associated predicted functions were determined using bioinformatics tools. Though marginal shifts in microbial community structure were observed in response to elevated temperature, the PICRUSt predicted metabolic profiles revealed significant changes in key KEGG metabolic categories, including amino acid and carbohydrate metabolism and membrane transport. These results suggest that predicted near-future climate induced increases in seawater temperature may shift microbial community function and potentially impact sea urchin digestive physiology.

34.2 BROTHERS, J.R.*; LOHMANN, K.J.; University of North Carolina at Chapel Hill; *brotherj@live.unc.edu*

Magnetic Genetics: Sea Turtle Rookery Genetic Structures Provide Evidence for Geomagnetic Imprinting as a Mechanism of Natal Homing

Natal homing is a pattern of behavior during which animals leave their geographic area of origin before returning to reproduce in the same location where they began life. Despite evidence that natal homing is widespread, little is known about how it is accomplished. A recent idea, known as geomagnetic imprinting, notes that unique magnetic fields mark different geographic areas. Thus, animals that detect Earth's magnetic field, such as sea turtles, might learn the field that exists in their natal area when they are young and use this information to return as adults. While natal homing is well established in sea turtles, some populations show a perplexing genetic structure where adjacent nesting beaches are genetically distinct, but geographically isolated nesting beaches are genetically similar. These patterns could arise through magnetic navigation to natal beaches when distant beaches have similar magnetic fields and neighboring beaches have different fields. In these instances, a turtle searching for its natal beach might find a location with an appropriate magnetic field that is actually far from its target. Thus, the geomagnetic imprinting hypothesis predicts that, regardless of geographic distance, nesting beaches with similar magnetic fields should be genetically similar, and nesting beaches with different fields should be genetically distinct. Analyses of published data confirmed this prediction; we found that spatial variation in Earth's field is a strong predictor of genetic differentiation, while geographic distance is not. The results corroborate initial reports that geomagnetic imprinting underlies natal homing and suggest that sea turtle genetic structure is, at least in part, mediated by magnetic navigation to nesting sites.

P1.66 BROWN, CJ*; MILLER, RL; CLOSE, MT; Radford University; *Cbrown14@radford.edu*

Does Size Matter?: A Look At Meal Regulation in Juvenile Snakes

In animals, meal size is determined by numerous endocrinological and neurological factors, and in juveniles of species with post-natal parental care, meal size is in part regulated by the parental guidance or direct provisioning. However, in animals that have very limited or complete lack of post-natal parental provisioning, it is assumed that meal size is determined primarily by intrinsic factors and experience. For gape limited predators, such as snakes, this approach may lead to costly mistakes in attempting to capture, ingest, and digest large prey. In this study, we explored whether and how juvenile snakes determine prey size. We observed feeding records from juvenile Texas rat snakes (*Pantherophis [Elaphe] obsoletus lindheimeri*) fed small, medium and large prey, and measured the effect of prey size on search, approach, contact, and ingestion behaviors. Our results show that juvenile snakes spend equal amount of time searching and approaching prey regardless of relative prey size, but spend more time in direct contact with relatively large prey. Furthermore, while there was no difference between large, medium and small prey juvenile in number of tongue flicks, snakes spent more time chin rubbing and biting prey prior to attempting to ingest them. Our data suggest that while snakes rely on chemo-sensory and possibly visual cues to assess preference and locate prey, snakes may rely on tactile cues to determine size of prey in close proximity. Because juvenile snakes will attempt to handle and ingest prey that are too large to consume, we propose that handling time and stress may play important roles in shaping snake diets during early experiences.

11.6 BROWNE, L*; KARUBIAN, J; BROWNE, Luke; Tulane University; *lukembrowne@gmail.com*

Frequency Dependent Selection for Rare Genotypes Promotes Genetic Diversity of a Tropical Palm

Negative frequency dependent selection among species is a key driver of community diversity in natural systems, but the degree to which negative frequency dependent selection shapes patterns of survival and genetic diversity within species is poorly understood. In a five-year field experiment in the Choco rainforests of northwest Ecuador, we show that seedlings of the tropical palm *Oenocarpus bataua* with rare genotypes had a pronounced survival advantage over seedlings with common genotypes, with effect sizes (i.e., regression coefficients) comparable to that of light availability. This 'rare genotype advantage' led to an increase of population-wide genetic diversity among seedlings compared to null expectations, as predicted by negative frequency dependent selection, and increased reproductive success in adult trees with rare genotypes. We also investigate the role of long-distance seed dispersal in introducing rare genotypes into the population. These results suggest that within-species negative frequency dependent selection of genotypes can shape genetic variation on ecologically relevant timescales in natural systems and may be a key, overlooked source of non-random mortality for tropical plants.

S2.9 BROWNSCOMBE, Jacob, W.*; COOKE, Steven, J.; ALGERA, Dirk; BURNETT, Nicholas, J.; ELIASON, Erika, J.; DANYLCHUK, Andy, J.; HINCH, Scott, G.; FARRELL, Anthony, P.; Carleton University; *jakebrownscombe@gmail.com*

The ecology of exercise in wild fish - integrating concepts of individual physiological capacity, behaviour and fitness through diverse case studies

Wild animals achieve fitness through certain behaviours (i.e., foraging, mating, predator avoidance) that often require high levels of locomotor activity. The ability of animals to achieve fitness may therefore be related to their physiological capacity for exercise relative to the energetic constraints imposed by ecological factors such as temperature, predators, or landscape characteristics. Here, through a series of case studies, we explore how ecological factors and physiological limitations influence teleost fish exercise and energetics in relation to fitness related activities. In marine environments, bonefish activity levels on foraging grounds are influenced by water temperature and peak at temperatures consistent with their metabolic optimum. The ability of Pacific salmon to successfully pass areas of challenging water flows is constrained by their physiological capacity for exercise; this may be a major limiting factor in whether individuals reach spawning grounds. Smallmouth bass allocate a significant amount of energy into nest-guarding behaviours to protect their developing brood, and their ability to successfully produce viable offspring is influenced by their body size and physiological state. These case studies on diverse fish taxa highlight the important role of exercise in achieving fitness, while also demonstrating how ecological factors impose energetic constraints on animals that shape physiological and behavioural characteristics. Here we outline a number of approaches to studying exercise in wild fish using biologging and biotelemetry platforms, and also consider some current methodological limitations and future research directions.

39.6 BROZEK, J.M.*; SCHNEIDER, J.E.; RHINEHART, E.; Lehigh University, Lehigh University , Susquehanna University; *jeremy.brozek@gmail.com*

Food restriction of mothers during gestation alters offspring growth and adult behavior in Syrian hamsters (Mesocricetus auratus).

Undernutrition during early development (for example, due to maternal food restriction) can lead to altered phenotypes in offspring, including low birth weight, postnatal catch up growth, early pubertal development, and a predisposition toward obesity. The effect of food restricting the pregnant dam has been studied in the offspring of laboratory rats and mice, species that tend to respond to energetic deficit by increasing consummatory behavior, i.e., food intake. Other species, including human beings, Siberian hamsters, and Syrian hamsters, do not increase food intake after a period of food restriction or fasting, but they do increase appetitive behaviors such as grocery shopping (humans) and food hoarding (hamsters). We hypothesize that both appetitive and consummatory behaviors are programmed prenatally by maternal food availability during gestation. Specifically, we predicted that maternal food restriction would lead to Syrian hamster offspring with low adult levels of food hoarding, high adult levels of food intake, earlier puberty, and high levels of food efficiency leading to obesity. We tested this hypothesis using a cross-foster design and 10% food restriction during gestation. We found that Syrian hamsters are more sensitive to gestational restriction compared to rats and mice, leading to low birth weight and catch up growth, but no effect on time of the first estrous cycle. Only the offspring with food-restricted mothers both pre- and postnatally showed significant increases in food intake in adulthood. Future studies will test whether or not maternal food availability during gestation can influence the ability to switch between food and sex behavior in mature adults.

P1.154 BRUEGGEMANN, N.; DAVIS, C.; WILLIAMS, J.B.*; Southern Illinois University, Edwardsville; *jasowil@siue.edu*

The effect of cholesterol and γ-tocopherol on cold tolerance, post-cold performance, and rapid cold hardening

Increasing membrane cholesterol content through augmented diets can enhance insect cold tolerance and rapid cold hardening (RCH). However, cholesterol is not readily available to phytophagous insects in nature. By contrast, other membrane ordering molecules, such as γ-tocopherol is readily available and is seasonally accumulated in some cold-adapted insects. To determine if γ-tocopherol also functions to enhance cold tolerance, survival to low temperature, ability to RCH, and recovery from chill coma was measured on *Drosophila melanogaster* fed either normal or supplemented food (cholesterol and/or γ-tocopherol). Flies fed food augmented with cholesterol or γ-tocopherol survived exposure to -6°C at a higher rate (71.2 ± 2.9 and 37.1 ± 1.6 %) than those fed a normal diet (2.3 ± 2.2%). In addition, animals fed augmented food were better able to pass a vertical walking test immediately after, and 12h after an exposure to 0°C for 5h (averaging 18.3 ± 2.4% and 83.2 ± 2.1%) than those fed a normal diet (2.3 ± 0.8%, 71.5 ± 2.3%). Furthermore, supplementation with cholesterol and γ-tocopherol enhanced a fly's ability to RCH as 94.7 ± 1.0% and 82.9 ± 6.2% of those subjected to 10°C for 2h prior survived a 1h exposure to -6°C compared to only 60 ± 3.6% for those fed non-supplemented food. Lastly, augmenting food with cholesterol and/or γ-tocopherol also reduced chill coma recovery time from 19.2 ± 0.3 to 15.5 ± 0.4 min in animals exposed to 0°C for 5h after RCH. In summary, both cholesterol and tocopherol augmentation increased survival to low temperature, post-cold performance, and enhanced RCH.

121.4 BRUSCHG, GA*; DENARDO, DF; Arizona State University; *bruschg@gmail.com*

Hydration Immunology: The Relationship Between Hydric State and Immune Performance

Immune function can vary based on resource availability, and most studies of such influences have focused on the co-investment of energy into immune and other physiological functions. When energy resources are limited, trade-offs exits, which can compromise immunity for other functions. As with energy, water limitations can also alter various physiological processes, yet water has received little consideration for its role in possibly modulating immune functions. We examined the relationship between immunocompetence and hydration state using the western diamond-backed rattlesnake (*Crotalus atrox*). This species is known to undergo substantial seasonal fluctuations in water availability, experiencing periods of considerable dehydration during the seasonal drought. To measure changes in plasma osmolality and immune function over time, we withheld food and water from individually housed adult *C. atrox* held in an environmental chamber for 16 weeks. We collected blood from each animal as they dehydrated and collected a final sample after animals were given ad lib water at the end of the experiment. We examined the relationship between immunocompetence and hydration state using several plasma assays to assess innate immune function- lysis, agglutination, bacterial killing. To ground-truth our laboratory work, we collected blood samples from free-ranging *C. atrox* during the milder and relatively moister early spring season, during the hot-dry season, and during the hot-wet season. We determined the osmolality of these samples and performed the same immune function assays used for the laboratory study. Results from both the lab and field experiments produced consistent but counter-intuitive results demonstrating that dehydration enhanced innate immune mechanisms.

91.2 BRYANT, HJ*; SCHULTE, PM; University of British Columbia, Vancouver; *hbryant@zoology.ubc.ca*

Uncoupling Proteins and Thermal Acclimation and Adaptation in Atlantic killifish, Fundulus heteroclitus

Mitochondria are a critical component of an animal's response to environmental stressors such as temperature, as they are the primary site of aerobic energy production. Mitochondrial uncoupling proteins (UCPs) are known to be involved in temperature responses in mammals, for example by helping to generate heat in mammalian brown adipose tissue upon cold exposure. UCPs are also present in ectotherms but their functional role in these animals is not well understood. Here we use Atlantic killifish, *Fundulus heteroclitus*, as a model organism in which to address the role of UCPs in thermal acclimation and adaptation in ectotherms. Atlantic killifish are broadly eurythermal and display extensive phenotypic plasticity in response to thermal acclimation. In addition, there are geographically separated subspecies that differ in their thermal biology, making this an ideal system in which to investigate mechanisms of acclimation and adaptation to temperature. To characterize UCPs in killifish, the gene sequences and tissue-specific expression of members of the UCP family (UCP1, UCP2, UCP3, UCP3-like and UCP5) were determined. In general, the tissue-specific expression of these genes was similar to those reported in other fish species. Most isoforms differed in mRNA expression levels between subspecies, but not with thermal acclimation. However, the fish-specific isoform, UCP3-like, that is primarily expressed in gill tissue, was not responsive to thermal acclimation in the northern subspecies, but in the southern subspecies, mRNA expression declined with increasing temperatures. The functional consequences of this change in gene expression plasticity between the subspecies are currently being investigated.

P1.60 BRYCE, C.M.*; ARTHUR, S.A.; BORG, B.L.; WILMERS, C.C.; WILLIAMS, T.M.; Univ. of California, Santa Cruz, Arctic National Wildlife Refuge, Denali National Park and Preserve; *cbryce@ucsc.edu*

The effects of prey and habitat heterogeneity on Denali wolf movements and energetics

Animal movement is dependent upon metabolic energy, the fundamental currency of ecology. Yet quantifying the activity patterns and energy demands of wide ranging keystone predators such as gray wolves (*Canis lupus*) in the wild has remained exceedingly difficult, resulting in a poor understanding of how physiological capabilities and environmental factors affect animal movement and foraging success. We deployed accelerometer-GPS collars on wolves in Denali National Park to gain unprecedented detail into travel patterns, foraging, and daily energetic costs of these carnivores. In 2015, 20 wolves across DENA's northern expanse were monitored continuously in distinct lowland spruce (Region 1), upland (Region 2), and open foothill (Region 3) habitats with known differences in relative prey availability and type including moose, caribou, Dall sheep, and salmon. Wolves occupying habitat that supported salmon but few large ungulates (Region 1) had the lowest within-pack wolf densities (0.3 wolves/1000 km2) and the smallest average pack size (2.2 wolves/pack in 4 packs) relative to regions with more abundant ungulate prey and topographic complexity (Region 2: 0.5 wolves/1000 km2 and 5.6 wolves/pack in 6 packs; Region 3: 0.8 wolves/1000 km2 and 5.3 wolves/pack in 2 packs). Daily distance traveled for wolves in Region 2 (14 km/day) was significantly less than for wolves in Regions 1 and 3 (19 and 20 km/day, respectively), corresponding to reduced foraging costs for wolves defending territories with more ungulate prey. Identifying such patterns in wolves represents a critical step towards evaluating how natural features and heterogeneous prey distribution influence space use and energy allocation, with subsequent conservation implications in Alaska and beyond.

23.1 BUBAK, AN*; WATT, MJ; RENNER, KJ; SWALLOW, JG; University of Colorado-Anschutz Medical Campus, University of South Dakota-Sanford School of Medicine, University of South Dakota, University of Colorado-Denver; *Andrew.Bubak@ucdenver.edu*

Serotonin-mediated aggression: sex-dependent roles in regulating neuropeptides

Aggression is a complex and nearly universal behavior, documented in animal species ranging from humans to flies. Based on comparative research investigating the proximate mechanisms responsible for the appropriate perception and execution of aggressive behaviors, it is clear that genes and neurochemicals (i.e., biogenic amines, hormones, neuropeptides) that mediate this suite of behaviors are conserved across a wide range of taxa. The serotonergic (5-HT) system, in particular, shares deep evolutionary origins between vertebrates and invertebrates and has been largely implicated in aggressive behavior. However, most of our understanding with respect to the mechanisms of the serotonergic system derives from manipulations that result in global 5-HT changes and have predominantly been male-focused studies. To better understand the system and the role of 5-HT we need to target individual genes such as receptor subtypes as well as their interactions with other neurochemical systems known to mediate aggression. Additionally, to have a thorough understanding of this complex behavior, both mechanistically and evolutionarily, it is imperative that we investigate the similarities and differences between sexes. I will discuss our findings that focus on 5-HT receptor subtypes and their specific roles in mediating other neurochemical systems, specifically tachykinin and neuropeptide F, and how these mechanisms differ between sexes in a novel dipteran model of aggression.

9.1 BUBAK, AN; HOOVER, KM; RENNER, KJ; SWALLOW, JG; GREENE, MJ*; University of Colorado Denver, University of South Dakota; *michael.greene@ucdenver.edu*

The role of brain monoamines (serotonin (5-HT), octopamine, and dopamine in pavement ant aggression

Ant colonies are distributed systems that are regulated in a non-hierarchical manner. Without a central authority, individuals inform their decisions by comparing information in local cues to a set of inherent behavioral rules. Collectively, many individual behavioral decisions lead to changes in colony behavior including the decision to be aggressive with neighboring colonies. Pavement ants (*Tetramorium caespitum*) form conspicuous wars with neighboring colonies in which thousands of ants participate. Wars last for many hours and few workers die in the process as fighting is ritualized. A worker will decide to fight if 1) it has had a recent history of interactions with nestmates and 2) detects a mismatch in nestmate recognition cues on the cuticle of a non-nestmate ant. We present evidence showing how tactile and chemical cues and social context - isolation, nestmate interaction, or fighting non-nestmates - affect levels of the brain monoamines serotonin (5-HT), octopamine, and dopamine in pavement ant brains. Interactions with nestmate ants prior to meeting a non-nestmate opponent elevate 5-HT and octopamine levels in a worker's brain. If levels of 5-HT and octopamine are above a threshold when the ant detects non-nestmate chemical cues, it is likely to fight the opponent. Pharmacologically increasing brain levels of 5-HT and serotonin make it more likely that an ant will fight an opponent, even if that ant had not recently interacted with nestmate ants. Dopamine levels are elevated during fighting. Our results provide correlational and causal evidence that changes in octopamine and serotonin in the brains of individuals contribute to the collective-decision to be aggressive whereas dopamine levels correspond specifically to physical fighting.

142.4 BUCHANAN, JL*; MONTOOTH, KL; University of Nebraska, Lincoln; *justin.l.buchanan@gmail.com*

Sex-Specific Effects of Compromised Energy Metabolism on Immunity and Life-History

The physiological responses of organisms to short-term environmental stress, such as infection, can have long-term consequences for fitness, particularly if responses are inappropriate or nutrient resources are limited. Physiological responses to pathogens in the environment can be energetically costly, drawing on energy resources that would otherwise be devoted to organismal growth, maintenance, and reproduction. This energy balance can generate life-history tradeoffs that may shift through development and are likely influenced by external factors such as infection, environmental changes, and resource availability. While the pathways of immune responses are well-characterized, how organismal responses to infection are impacted by energy limitation is not well understood. Yet, the pathways that mediate innate immune responses and that respond to nutrient availability are connected. Here I use well-characterized mitochondrial-nuclear genotypes of the fruit fly, *Drosophila melanogaster*, that have compromised aerobic energy metabolism to test for effects of compromised energy metabolism on infection and life-history traits using a natural bacterial pathogen. My results demonstrate that adult survivorship post infection is significantly decreased in energetically compromised genotypes relative to wildtype controls, but only in females. However, energetically compromised individuals that survive infection produce a similar number and quality of offspring relative to uninfected individuals. Thus, while females do show expected phenotypes of compromised energy metabolism on the ability to fight infection, the effects on the future reproduction of females surviving infection are minimal when provided optimal resources during adulthood.

10.4 BUCHINGER, TJ*; BUSSY, U; LI, K; WANG, H; BAKER, CF; HUERTAS, M; JIA, L; HAYES, MC; LI, W; JOHNSON, NS; Michigan State University , bNational Institute of Water and Atmospheric Research , United State Geological Survey; *buching6@msu.edu*

Evolution of pheromone communication in lampreys

Pheromone communication is generally considered highly species-specific due to the intricate mechanisms of signal production and detection. While research on pheromone communication in insects supports a role of multi-component pheromones in speciation and reproductive isolation, pheromone communication in vertebrates is rarely considered across a phylogeny and, as a result, the evolution and specificity of vertebrate pheromones remained poorly understood. Here, we present our ongoing effort to describe the species specificity of mating pheromones across the Petromyzontiformes. The sea lamprey (Petromyzon marinus) uses a multi-component male mating pheromone, comprised of the major component 7α, 12 α, 24-trihydroxy-3-one-5 α -cholan-24-sulfate (3kPZS) and several additional components. Phylogenetic comparisons of the 3kPZS communication indicate that female preference for 3kPZS arose in a non-sexual context, and that 3kPZS is used as a mating pheromone in at least one other species of lamprey. Sea lamprey respond to heterospecific odors that lack 3kPZS, indicating that minor components of the pheromone blend may be conserved and function independently of 3kPZS. Describing species-specificity of lamprey pheromones will not only provide insights into the evolution of vertebrate pheromone communication, but also shed light on the role of pheromone blends in reproductive isolation among sympatric lampreys and pheromone-mediated reproductive interference between the native and invasive lampreys.

P3.34 BUCHOLZ, J. *; COHEN , C. S. ; HUEY , B. ; ERBEL , R. ; PARK, S. ; UW-River Falls , Romberg Tiburon Center, Biology, San Francisco State University , Santa Rosa Junior College ; *jbucholz93@gmail.com*

Sea Star Wasting Disease Etiology in Leptasterias spp.

Sea star wasting disease (SSWD) has affected > 20 species of sea stars along the Pacific coast since 2013. Small stars like the six-rayed *Leptasterias* initially appeared resistant as the larger sea stars died off in locations where *Leptasterias* persisted. Now strong impacts are seen in *Leptasterias* spp as well. Best characterized in the larger species like *Pisaster ochraceus*, symptoms of SSWD include white lesions, tissue disintegration, and death. The pathogen or pathology may differ among species. Smaller stars may progress swiftly through SSWD making characterization of incidence and progression hard. *Leptasterias* spp. show variation in color pattern, particularly in white areas, that are hard to distinguish from early SSWD. To gauge the effects of SSWD, both healthy and symptomatic *Leptasterias* spp. collected from intertidal sites in California, and Oregon, were monitored daily in the lab for disease progression and photographed under a dissecting microscope. Stars received either a treatment of magnesium chloride ($MgCl_2$) and ice (n=4) or a control group of ice (n=5) to relax them for photography. Treated stars lived from three to forty-six days, exhibiting a slowed disease progression, while control stars lived three to seven days from the sign of initial lesions to death. Variability of symptoms was noted, indicating multiple disease progressions. Etiologies ranged from lesions starting in the axilla and spreading down the rays, holes in the central disk, and lesions starting at the optic cushion and spreading up the rays. Symptoms mirror those seen in *P. ochraceous*, excluding the holes starting in the central disk, suggesting the same pathogen or pathology may affect the initially resistant small stars.

S4.5 BUCKLEY, LB*; ARAKAKI, A; KHAROUBA, HM; KINGSOLVER, JG; Univ. of Washington, Seattle, Univ. of Ottowa, Univ. of North Carolina, Chapel Hill; *lbuckley@uw.edu*

Insect Development, Thermal Plasticity and Fitness Implications in Changing, Seasonal Environments

Recent climate change has advanced seasonal timing (phenology) in many animals and plants, particularly in temperate and higher latitude regions. The population and fitness consequences of these phenological shifts for insects and other ectotherms have been heterogeneous: warming can increase development rates and the number of generations per year (increasing fitness), but can also lead to seasonal mismatches between animals and their resources and increase exposure to environmental variability (decreasing fitness). The developmental responses of insect populations to temperature contribute to seasonal adaptation to local climate conditions; but climate change can potentially disrupt seasonal timing of juvenile and adult stages and consequently population fitness. We investigate these issues using a global dataset for the developmental responses of insects to temperature, focusing on two types of traits: lower temperature thresholds for development (T0), and the cumulative degree-days required to complete development (DDD). We explore how these traits vary across gradients in seasonality (latitude). We then use the traits to predict developmental timing and temperatures experienced during development for multiple generations within seasons and across years. Our preliminary analyses suggest that the curvature describing variation in temperatures and generation length peaks at mid latitudes where the growing season is sufficiently long to experience pronounced seasonality. Phenological advancements over recent decades peak at poleward latitudes, whereas increases in the potential number of generations peak at mid latitudes. Shifts in developmental and adult temperatures vary. Developmental shifts due to climate change will have complex implications for selection and fitness in seasonal environments.

33.4 BUCKNER, JC*; ELLINGSON, R; GOLD, DA; JACOBS, DK; Univ. of California, Los Angeles; *jcharrayb@ucla.edu*

Sequencing Dead Ducks - The Labrador Duck is Sister to Stellar's Eider and the Subfossil Chendytes lawi roots the dabbling duck clade

Morphological assessments of 2.5 thousand year old *Chendytes*, fossil flightless anseriforms from coastal California, revealed characters related to diving and led to assignment of the species to the sea ducks (Mergini). Using a bait approach, we recovered complete mitochondrial sequence of seven purported Mergini species, including *Camptorhyncus labradorius* (the recently extinct Labrador duck) and *Chendytes lawi*. Phylogenetic analyses places *C. labradorius* as sister to Steller's Eider within the Mergini. However, the placement of *Chendytes* as a basal member of Anatini (dabbling ducks) supports evolution of dabbling from diving. Our study shows how recently extinct relict lineages can strongly influence our inferences about biogeography and diversification of modern groups when properly placed on phylogenetic trees.

P1.177 BUI, H*; CURRY ROGERS, K; ROGERS, R; Macalester College; *rogersk@macalester.edu*

Pathological Vertebrae in Sauropod Dinosaurs from the Upper Cretaceous Maevarano Formation of Madagascar

A collection of disassociated caudal vertebrae belonging to two titanosaurian sauropod taxa (*Rapetosaurus* and Malagasy Taxon B) from the Maevarano Formation of Madagascar record unusual osteopathological lesions. In a survey of 85 caudal vertebral centra from 30+ young juvenile individuals, abnormalities were identified in 46 specimens. Lesions vary in shape and size, and their presence varies in distribution along the tail. They are present on both anterior and posterior vertebral articular surfaces. In some specimens, multiple lesions occur on a single surface. The lesions vary in shape, and can be categorized as curvilinear, linear, pit/divot, C-shaped, T-shaped, or irregular. Lesions are not the result of post-mortem or pre-depositional taphonomic processes such as weathering or breakage: lesion boundaries are clear and complete, and vertebrae are exceptionally well preserved. These lesions are most similar to neontological Schmorl's nodes, intervertebral disc herniations that penetrate the adjacent vertebral endplate and stimulate bone remodeling. Schmorl's nodes are commonly recorded in the lumbar region of the human vertebral column due to trauma or repetitive movements that cause the nucleus pulposus of the intervertebral disc to bulge into and reshape the articulating vertebral face. These spinal abnormalities occur under bending or compressive loads, and are more likely to occur with the weakening of the spinal column due to old age. They can be associated with other spinal pathologies such as kyphosis and/or osteoporosis. Currently, there is no consensus on the pathogenesis of Schmorl's nodes. Their frequent occurrence of this pathology in the titanosaur sample may reflect biomechanical loading in the caudal region, perhaps linked to an unknown behavior in juvenile sauropods.

P3.161 BUNGE, ZD*; BIBER, J; FERGUSON, SB; MEDLER, S; SUNY Fredonia; *scott.medler@fredonia.edu*

Integrating research and undergraduate education: cloning ghost crab myosins

Ghost crabs exhibit remarkable running capabilities that are comparable with similar sized mammals, and their performance is clearly dependent upon the cellular and molecular organization of their skeletal muscles. Skeletal muscle function in mammals and other vertebrates is closely linked to the specific myosin heavy chain (MHC) motors that power muscle contraction. In crustaceans, distinct fiber types are closely correlated with muscle function, but our understanding of the MHC isoforms in these distinct fiber types is more rudimentary than in mammals. We have previously identified partial sequences from ghost crabs that included the carboxy-terminus and 3'-UTR of three different MHC isoforms, but the only full-length MHC sequences known from any crustaceans are from three species of shrimp. The current project began as the central component of a research-based laboratory course, and as such represents the productive integration of authentic research with the teaching mission of a predominantly undergraduate institution. Our goal in that course was to identify the full-length sequence using 5' RACE to clone amino-terminal ends of the MHC genes in different muscle fiber types. The sequences obtained in the class, together with the previously identified 3' end of the genes, were used to design PCR primers to fill in the sequence gaps in these 6 kb genes. Using numerous complementary methods partial cDNA clones were generated and range from 4,400-4,800 bp and have been identified and statistically compared to other MHC gene sequences known from the shrimp. Once we complete our identification of the full length sequences of the three MHC isoforms in ghost crabs, we will compare these with the available sequences from other decapod crustaceans to better understand how these genes contribute to the ghost crab's remarkable running performance.

s6.7 BURMEISTER, S.S.; University of North Carolina; *sburmeister@unc.edu*

The Preoptic Area as a Gatekeeper to Mate Choice in Frogs

The preoptic area is a highly conserved member of the social behavior network of vertebrates, although relatively little is known about its role in the behavior of anurans. The anuran preoptic area is better known as part of an audioendocrine circuit that mediates effects of social cues on gonadal function (ovulation in females, androgen secretion in males). At the same time, extensive evidence points to the importance of the auditory midbrain (i.e., torus semicircularis/inferior colliculus) in mediating behavioral responses to mating calls. Yet, accumulating evidence suggests that the preoptic area may play an important role in the expression mating preferences of anurans. Neuroanatomically, the preoptic area is poised to mediate forebrain influences on auditory response of the midbrain, and it has descending projections to the medulla and spinal cord that could directly influence motor responses. Indeed, lesions of the preoptic area abolish phonotaxis. We have found that, in túngara frogs, estradiol enhances responses of the preoptic area to mating calls in a manner that mirrors the effects of estradiol on phonotaxis. In contrast, while estradiol increases auditory responses in the midbrain, it appears to simply lower its threshold to all calls. Likewise, in spadefoot toads, we find that catecholamine levels in the auditory midbrain respond to the acoustic properties of mating calls independently of mate preferences. In the preoptic area, catecholamines demonstrate significant plasticity in response to mating calls, in a pattern that predicts preferences. Thus, a combination of neuroanatomy, direct tests of function, and associations between neural response patterns and mate choice behavior point to the preoptic area as a gatekeeper of mating preferences in frogs.

49.5 BURNETT, N.P.*; KOEHL, M.A.R.; Univ. of California, Berkeley; *burnettnp@berkeley.edu*

Kelp epifauna depend on and affect kelp structure and growth

Macroalgae attached to wave-swept rocky shores can form canopies that provide habitat and food for many other organisms. Large seaweeds can outcompete neighbors for space and light, but are at greater risk than smaller seaweeds of being damaged or dislodged by hydrodynamic forces, especially in the winter when seasonal storms produce large ocean waves. We used the kelp *Egregia menziesii*, a dominant canopy-forming intertidal kelp along the California coast, to examine how kelp structure (i.e. total size, number of fronds) changed seasonally and over the lifetime of a kelp, how the kelp structure influenced the presence of epifauna on the kelp, and how the grazing by epifauna influenced the structure of the kelp. Through long-term surveys of *E. menziesii* populations at several sites in northern California, we found that fronds usually break rather than being totally lost, and that the broken fronds produce new branches. Therefore, these kelp typically become more branched and have more fronds over the course of their lives. *E. menziesii* with many fronds tend to host more herbivorous epifauna, such as limpets, amphipods, isopods, and kelp crabs. Grazing by these animals can wound fronds, which are likely to break at such injuries. Thus, epifaunal herbivores can facilitate the shortening of fronds, which in turn causes the kelp to become more branched and to thus host more grazers. The shortening of the fronds in the late fall and winter is an important process that helps *E. menziesii* reduce its overall size and survive winter storms, but maintaining a large number of fronds through winter is also important for ensuring that the kelp can begin the next year ready to compete against neighboring kelp for space and light.

140.4 BURNETTE, MF*; ASHLEY-ROSS, MA; Wake Forest University; *burnmf0@wfu.edu*

Motor patterns of cranial muscles during spitting in the archer fish (Toxotes chatareus): the role of target distance

Archer fishes (Toxotidae) are capable of firing jets of water from their mouths that can dislodge potential prey (for instance, an insect) from overhead vegetation. It has been demonstrated that the fish can determine the distance to a potential target and can use this information to influence how the stream behaves as it is travels to and hits the target. When the fish fires a shot, the water leaving the mouth is initially stream-like; as it travels, the stream comes together as a large mass just before impact. The fish is known to be able to adjust when this merging occurs with target distance. What is currently not known is how the muscles that propel the jet are coordinated to accomplish this merging effect; evidence from suction feeding studies in other teleost fish has shown that very different cranial muscle motor patterns can produce similar values of buccal pressure, and thus, water flow into the mouth. The motor patterns of spitting in archer fish may also show as much variation. Here, we used electromyography (EMG) to quantify the duration, onset, and offset times for three cranial muscles in *T. chatareus* that are known to be active during spitting: the geniohyoideus, the adductor operculi, and the adductor mandibulae muscles. We placed targets at two distances from the water surface: two body lengths (BL) and six BL. Overall, we found that the archer fish increased mean muscle burst duration for all three muscles as target distance increased from two to six BL. Onset times of muscle activation largely remained the same between the two target distances, but offset times were later for shots fired at the more distant target presented. These findings further support the idea that the fish is using target distance information to tune the motor patterns during jet propulsion.

54.1 BURNS, M*; HEDIN, M; TSURUSAKI, N; San Diego State University, Tottori University; *mercedes.burns@gmail.com*

Population Genomics and Geographical Parthenogenesis in Japanese Harvestmen (Opiliones, Sclerosomatidae)

Geographical parthenogenesis refers to the common association of widely dispersed asexual populations with more narrowly distributed sexual populations. Some research supports the adaptive advantages of temporary or facultative asexuality as a colonization strategy. Other work points to a non-adaptive rationale for the association of asexuality to habitat margins, because parthenogens frequently display hybrid ancestry, genome duplications often precede parthenogenetic ability, and admixture of sexuals and asexuals within populations is expected to be rare. We explore support for these hypotheses in two Japanese species of harvestmen, *Leiobunum manubriatum* and *Leiobunum globosum*. Reproduction in these species proceeds with or without male fertilization, and female-biased localities are common in high-latitude and elevation habitat margins. Karyotypic and cytometric work indicates *L. globosum* is entirely tetraploid, while *L. manubriatum* has both diploid and tetraploid lineages. Using next-generation sequence data, we estimated genetic differentiation, diversity, and mitonuclear discordance in females collected at high and low latitude and elevation in order to evaluate genetic indicators of adaptation in specimens from marginal habitat. Our results point to northward expansion of *L. manubriatum*, coupled with support for increased male gene flow. Specimens from localities in the Tohoku and Hokkaido regions were indistinct, particularly in *L. globosum*, potentially due to little mitochondrial differentiation or haplotypic variation. Ongoing molecular work will serve to elucidate reproductive mode within and potential for hybridization between these putative populations.

126.4 BURRESS, ED*; TAN, M; ARMBRUSTER, JW; Auburn University, Emory University; *edb0014@auburn.edu*

The Evolution of Pharyngeal Jaw Shape, Size, and Associated Musculature across the Neotropical Cichlid Phylogeny

Key innovations have periodically led to salient leaps in functional capacity, efficiency, and/or versatility. A series of modifications to the pharyngeal arches that resulted in a second functional set of jaws (i.e., the pharyngeal apparatus) are hypothesized to represent a major innovation that promoted diversification among cichlid fishes. Here, we test the degree of coevolution, or decoupling, among major functional aspects of pharyngognathy across a phylogeny of 97 Neotropical cichlids: pharyngeal bone shape, pharyngeal bone mass, and the mass of the musculature that operates the biting motion of the pharyngeal jaws. The masses of the lower pharyngeal jaw (LPJ) and muscular sling (MS) were correlated. In contrast, LPJ shape was not correlated with the masses of the LPJ or the MS; however, LPJ shape was correlated with body shape. LPJ and MS masses were variably constrained depending on LPJ shape. For example, species with narrowly-spaced LPJ lateral processes exhibited exclusively atrophied LPJ and MS masses. In contrast, species with widely-spaced LPJ lateral processes exhibited an array of LPJ and MS masses. The mass of pharyngeal bones and musculature are likely coevolved in association with the mechanistic generation of crushing force and subsequent tolerance of force-induced stress, whereas the shape of pharyngeal bones may be partly constrained by body shape. Modifications of LPJ size, shape, and associated musculature in concert is associated with the evolution of an array of trophic functions.

P1.142 BURTON, CT*; WORKING, CL; VO, M; SURBER, LL; LIN, H; GEARHART, LM; REED, SY; JANG, CE; SMITH, JE; Biology Department, Mills College, Oakland, California 94613, Mills College; *jesmith@mills.edu*

Fecal glucocorticoid metabolites reflect endogenous and environmental factors in free-living California ground squirrels

As the world becomes increasingly modified by humans, many wild animals are facing novel suites of environmental stimuli. Chronic stressors, such as sublethal effects imposed by predators, including humans, may negatively influence the stress physiology of wild animals. Because California ground squirrels (*Otospermophilus beecheyi*) face both naturally occurring and anthropogenic threats, they provide a useful model for exploring relationships between predator exposure, human activity, and stress physiology. Here, we use a fully-validated and minimally-invasive enzyme-linked immunosorbent assay (ELISA) to measure fecal corticosterone metabolites (FCMs) of free-living *O. beecheyi* in northern California. As part of a long-term study of marked individuals, we monitored FCMs from individuals of both sexes across ontogeny and over multiple seasons, study sites, and years. We did this in an effort to explain the endogenous and environmental factors shaping baseline stress in these animals. Although adults tended to have the highest FCM levels, the effects of mass on FCM levels varied with the sex of the animal and its day of capture within the year. Beyond these effects, our study reveals significant differences between study sites, a finding that is consistent with the hypothesis that increased predator pressure from humans and off-leash dogs represents a stressor for these wild animals. Moreover, our analysis revealed that FCM levels vary with time of day and across years of the study. Taken together, our results suggest that the stress responses in free-living mammals are shaped by multiple endogenous and environmental factors, including encounters with humans.

42.1 BURY, A*; NIEDOJADLO, J; CICHOŃ, M; SADOWSKA, ET; SPEAKMAN, JR; BAUCHINGER, U; Jagiellonian University, University of Aberdeen; *agata.rozik@doctoral.uj.edu.pl*

Differential Relationship between Metabolic Rates and Hematological Variables in Exercised and Non-exercised Birds

Blood carries the oxygen supply for aerobic metabolism. Hematological variables (HV), specifically hemoglobin concentration (Hb), hematocrit (Hct), erythrocyte count (RBC_c) and area (RBC_{area}) may affect metabolic performance. However, the relationships between these four HVs and metabolic rate have not been explored in adult birds. We manipulated the energy requirements of female zebra finches (*Taeniopygia guttata*) by exercising them and investigated if specific HVs are related to energy expenditure and set limits to metabolic performance. In outside aviaries 56 birds were flight exercised twice a day for 90 min, while 46 birds remained as non-exercised controls. After 6 weeks the HVs, rho-phase basal metabolic rate (BMR_ρ) and maximum metabolic rate (MMR) were determined, and in a subset of 17 birds along with daily energy expenditure (DEE). Exercised birds had lower MMR than controls, but BMR_ρ, and DEE did not differ between groups. We attribute this to distinct thermoregulatory responses in treatment groups that masked exercise effects. Principal components (PC) were derived from HVs, and tested for their relationship to BMR_ρ, MMR and DEE. Hb, Hct and RBC_c were positively associated with PC1, and explained 60% of variation, while RBC_{area} had the highest positive input in PC2. MMR was not related to PC1 and PC2. BMR_ρ and DEE were significantly affected by interaction between PC1 and treatment. Interestingly, PC1 was positively related to BMR_ρ, but negatively to DEE, which was only significant in the exercised group. To conclude, MMR appears not to be driven by HVs, while BMR_ρ and DEE seem to be related to the combined levels of Hb, Hct and RBC_c, however in the opposite direction and only under exercise conditions.

136.8 BUSTAMANTE, J*; JANKAUSKI, M; DANIEL, TL; University of Washington; *jorgebjr@uw.edu*

Wasp waist: a tail of abdominal flexion, sensing, actuation, and flight control

Recent research suggests that abdominal actuation during insect flight may contribute to control and stability via inertial redirection of flight forces. All hymenoptera within the suborder Apocrita have a highly constricted segment of the abdomen called the petiole. This derived character can occupy up to 30-40% of the total body length and provide key insight into the possible dual roles of the abdomen as both an actuator and sensor for flight control. We used mud daubers (Sceliphron caementarium) as model organisms to ask if this structure has morphologies that are consistent with roles in both and sensing and flight control. We develop an Euler-Lagrange multibody dynamics model to predict flight responses to perturbations that arise from either external forces or internal muscle torques. Mechanical parameters for the model including the damping, mass, and spring constants of the abdominal segments were measured from tethered individuals subject to impulse and point load tests. The abdominal/petiole unit behaves as a damped mass system. Our multibody dynamics model also shows that the trajectory of the animal is sensitive to the geometry, position, and mechanics of the petiole and position of the abdomen. Thus changes in abdominal position with respect to the head/thorax position yields significant changes in the animal's trajectory (between a 1 cm rise and a 5 cm fall). Additionally, scanning electron microscopy (SEM) on preserved specimens reveals the existence of sensory hair plates at the base of peduncle-petiole joint, reminiscent of Böhm's bristles in antennal sensory systems. Moreover, the presence of sensory hair plates suggests that such small angular changes can be detected by the nervous system. Thus the dual roles of the abdomen are supported by our observations.

146.6 BUTLER, MW*; BAYLOR, J; Lafayette College; *butlermw@lafayette.edu*

Immune Challenges Result in Oxidative Damage, Which May Be Mitigated Via Antioxidant Activities of Biliverdin

While immune responses help hosts combat pathogens, there are also costs. One component of the immune response is the production of reactive oxygen species, which are useful for destroying pathogens, but also result in oxidative damage to the host's cells. To minimize this collateral damage, organisms may increase antioxidant availability. One potential antioxidant is biliverdin, the pigment most commonly associated with blue-green avian eggshell coloration. Here, we investigated two questions: 1) to what extent do different types of immune challenges result in oxidative damage, and 2) does biliverdin have a physiological role as an antioxidant? We found that two different immune challenges (administration of either lipopolysaccharide or phytohemagglutinin) result in similar increases in oxidative damage relative to controls over a 24-hour period. However, there was no treatment effect on body mass, change in body mass, circulating triglyceride levels, or biliverdin levels in circulation, the liver, or the spleen. Unexpectedly, we uncovered multiple correlations between biliverdin levels and circulating triglyceride levels, including an inverse relationship between biliverdin concentration in the liver and triglyceride levels in circulation. Also, regardless of treatment, birds that lost weight during the 24-hour experiment had greater levels of biliverdin in the liver and in circulation than those that gained weight. Lastly, we found negative correlations between biliverdin and oxidative damage in the plasma, supporting a putative antioxidant role for biliverdin. Because biliverdin concentration was associated with both circulating triglyceride levels and change in body mass, this molecule may have unexplored and important physiological roles in addition to acting as an antioxidant.

22.5 BUTLER, JM*; MARUSKA, KP; Louisiana State University; *jbutl48@lsu.edu*

Expression of tachykinin3 in socially-relevant brain regions is regulated by social status in the African cichlid fish Astatotilapia burtoni

Neurokinin B, encoded by the *tackykinin3* gene, is one of many neurohormones that work together to tightly regulate the reproductive axis. While previous research has mainly focused on *tac3* for its role in regulating reproductive endocrinology, it remains unknown if *tac3*-cells are activated during social interactions or if *tac3* expression is regulated by social state. To investigate how *tac3* expression varies with social and reproductive status in the African cichlid fish *Astatotilapia burtoni*, we used *in situ* hybridization to map and quantify *tac3* expression in the brains of dominant and subordinate males and ovulated and mouthbrooding females. *Tac3*-expressing cells were found in 20 different brain nuclei, and it was differentially expressed in approximately half of those regions. Dominant males had more *tac3*-expressing cells in the Vs, TPp, NLT, and PVO than subordinate males, and mouthbrooding females had more *tac3* cells in the NLT than gravid females, potentially due to estrogen feedback. In addition, dominant males and ovulated females had scattered cells in many socially-relevant telencephalic nuclei (e.g. Dm, Dlg, Vd), but these *tac3*-expressing cells were absent in subordinate males and brooding females. Double labeling for the immediate early gene *cfos* and *tac3* in the brains of fish collected after specific behavioral scenarios (i.e. spawning, territory defense) will determine whether any *tac3* cell populations are activated during social interactions. To our knowledge, no study has examined the role of *tac3* in social behaviors in fishes despite its known importance to the reproductive axis. Because expression differs with physiological state, it is possible that *tac3* has reproductive state-dependent neuromodulatory effects in mediating complex social behaviors such as territoriality and reproduction.

P2.145 BUTLER, JM*; MARUSKA, KP; Louisiana State University; *jbutl48@lsu.edu*

Underwater anthropogenic noise impacts aggressive interactions in a territorial African cichlid fish

Over the last few decades, underwater anthropogenic noise has increased ambient sound levels by >30dB in the range that most fishes detect and produce acoustic signals. Despite known effects on acoustic signaling, it remains largely unknown how social fishes cope with anthropogenic noise. In the territorial African cichlid fish *Astatotilapia burtoni*, social status is tied to reproductive success and is dependent on a male's ability to obtain and defend a spawning territory. Males use agonistic behaviors that generate water movements, which can stimulate the mechanosensory and auditory systems of nearby fish, but these signals may be masked by increased background noise. By observing territorial interactions in silent and noise playback conditions, we examined how high background noise impacts agonistic interactions in this highly territorial and social fish. During noisy conditions, fish had an increased latency to fight, and fights occurred in bouts instead of a single fight. Although the total time spent fighting did not differ, the increased time to resolution of the territorial dispute can have consequences on the energy expenditure and predation risk of fish. This altered fight structure may indicate that fish were distracted by the noise or had increased stress levels. Interestingly, fish fighting in noisy conditions appeared more brightly colored and spent more time with their eyebar displayed than those in silent conditions, suggesting an increase in visual signaling due to disruption in other sensory channels. To our knowledge, this is one of the first studies to examine how anthropogenic noise impairs social behaviors in a site-attached, soniferous fish species. As such, these results have important conservation and management implications for protecting against noise-induced effects on territoriality and reproductive success.

68.3 BYLE, J.*; CRUZ, A.; COHEN, M.; ROSCOW, R.; University of Colorado Boulder; *julie.byle@colorado.edu*

Brood Parasitism: The Host-Parasite Relationship of a Lake Tanganyikan Cichlid and a Cuckoo Catfish

The evolutionary benefit of mouthbrooding (the incubation of eggs in the mouth) is to increase offspring survival by sequestering the young during development and later releasing them in favorable locations. A prime example of maternal mouthbrooding in fish is the Lake Tanganyikan cichlid, *Centrocromis horei*. Interestingly, the cichlid itself is parasitized by a brood parasitic catfish, *Synodontis multipunctatus*. *S. multipunctatus* breeds exclusively by having the cichlid raise its young. When the cichlid is spawning, the catfish eats some of the eggs and simultaneously release its own gametes. The catfish larvae grow in the cichlid and potentially use the cichlid eggs as food sources. To understand the evolutionary consequences of brood parasitism on the cichlid, we firstly need to characterize this poorly understood ecological interaction. In this study, we documented cichlid mother size in relationship to her offspring clutch size and the rate of brood parasitism in *C. horei*. We also measured developmental growth rates of both species and their survival rates based on parasitized clutches. Our results showed that the size of female *C. horei* is positively correlated with the egg type and egg number in her clutch. Over a twenty-month period, 25.7% of *C. horei* clutches were parasitized by *S. multipunctatus*. The catfish absorbs its yolk sac by day 5, while it takes 21 days for the cichlid. The strategy appears to be beneficial to the success of *S. multipunctatus* and detrimental to *C. horei*. These findings provide a model system to study brood parasitism in controlled laboratory settings, where behavioral, developmental, and evolutionary questions about brood parasitism can be rigorously addressed.

P1.230 BYRNES, G*; ALLEN, JJ; LIM, NTL; CHENEY, JA; Siena College, Brown University, National Institute of Education, Singapore, Royal Veterinary College; *gbyrnes@siena.edu*

Structural properties of the gliding membrane of the colugo (Galeopterus variegatus)

Gliding evolved at least nine times in mammals. Despite the abundance and diversity of gliding mammals, little is known about their convergent morphology or mechanisms of aerodynamic control. Gliding animals are capable of impressive and agile aerial behaviors and their flight performance depends on the aerodynamic forces resulting from airflow interacting with a flexible, membranous wing (patagium). Although the mechanisms that gliders use to control dynamic flight are poorly understood, the shape of the gliding membrane (e.g., angle of attack, camber) is likely a primary factor governing the control of the interaction between aerodynamic forces and the animal's body. We examined the structure and mechanical properties of the colugo gliding membrane to generate hypotheses for mechanisms of wing shape control. We used cross-polarized light to visualize and describe numerous intra-patagial muscles. Evenly spaced muscle fiber bundles that could be involved in tension control or membrane packing occur both in the propatagium and uropatagium, running both parallel and perpendicular to the free edge of the patagium. The membrane is under tension when it is outstretched, suggesting the presence of internal, organized elastic tissue. We discovered that membrane material properties vary by location and orientation. Based on measurements, the patagium is stiffer in the craniocaudal direction than along the mediolateral axis. Similarly, the membrane is both thicker and stiffer near the body than near the free edge of the patagium. Both the abundance of intra-patagial muscle fibers and material anisotropy have consequences for membrane shape and likely allow for the high level of aerodynamic control exhibited by these animals during glides.

44.5 CABRERA-ÁLVAREZ, M*; BATTESTI, M; SWANEY, WT; READER, SM; McGill University, McGill University, Liverpool John Moores University; *maria.cabreraalvarez@mail.mcgill.ca*

Grouping Behaviour in Guppies after Intracranial Nonapeptide Administration

The mammalian nonapeptides oxytocin and vasopressin have robust and well-documented effects on social behaviour, while the avian homologues mesotocin and vasotocin also influence social behaviours such as flocking. In fish, however, the effects of the homologous nonapeptides isotocin and vasotocin are less well understood. In this study, we investigated the influence of nonapeptides on grouping behaviour in fish by measuring the time that wild-type guppies (*Poecilia reticulata*) spent close to a shoal and the time they spent interacting with the shoal after intracerebroventricular administration of isotocin, vasotocin, or putative receptor antagonists. Behaviour was monitored over a period of 2.5 hours after administration, and we found that isotocin significantly increased shoaling behaviour, while vasotocin significantly reduced interactions with the shoal, and that these effects both peaked 1.5 hours after administration. Our study demonstrates clear, and broadly opposing effects of the nonapeptides isotocin and vasotocin on shoaling behaviour. These results show clear similarities with the effects of homologous nonapeptides on grouping and social behaviour in other taxa, and offer support for a conserved role for nonapeptides on vertebrate social behaviour, albeit with species- and taxon-specific variation in the precise behavioural effects. Our results also highlight the importance of measuring the effects of nonapeptides over time rather than only immediately after administration.

P3.62 CABRERA-ÁLVAREZ, M*; SWANEY, WT; READER, SM; McGill University, McGill University, Liverpool John Moores University; *maria.cabreraalvarez@mail.mcgill.ca*

Activation of the Preoptic Area during Social Exposure in Guppies

Grouping behaviour has many benefits for individuals, such as reducing the costs of finding new foraging locations or reducing predation risk. Guppies (*Poecilia reticulata*) are social fish that live in groups in the rivers of Trinidad. Guppies, like many fish, prefer to join a larger shoal over a less numerous one. However, little is known about the brain regions that are active in teleosts during social exposure. Here, after confirming that wild-type guppies do indeed prefer to join a larger shoal, we investigated the activation of four brain regions proposed to be involved in social behaviour and reward. Subjects were exposed to a large shoal, a small one, or an empty tank, and we used immediate early gene expression (egr1) to assess neuronal activation. We found increased activation in the Preoptic Area when the fish were exposed to a large shoal compared to the control that had no social exposure. There were no significant differences in activation with social exposure within the other brain areas examined (dorsal and ventral parts of the ventral telencephalon, and ventral pallium). Our findings suggest possibilities for future work on social information processing in the Preoptic Area, known to be involved in the production of nonapeptides that modulate vertebrate social behaviour.

65.5 CAHILL, AE*; PEARMAN, JK; BORJA, A; CARUGATI, L; CARVALHO, S; DANOVARO, R; DASHFIELD, S; DAVID, R; FERAL, J-P; OLENIN, S; SIAULYS, S; SOMERFIELD, P; Aix Marseille Université, King Abdullah University of Science and Technology, AZTI, Marine Research Division , Università Politecnica delle Marche, Plymouth Marine Laboratory, Klaipeda University, Plymouth Marine Laboratory; TRAYANOVA, A; Bulgarian Academy of Sciences; UYARRA, MC; AZTI, Marine Research Division; CHENUIL, A; Aix Marseille Université; *acahill@albion.edu*

Community composition of hard-bottom macroinvertebrates in seven regional seas as measured using traditional and metabarcoding methods

Artificial sampling units (ASUs) allow for standardized sampling in the hard-bottom marine benthic environment, an area that is difficult to access for ecological studies. We deployed ASUs in 7 regional seas (the Baltic, Adriatic, Black, and Red Seas, the English Channel, the Bay of Biscay, and the Gulf of Lions) at a depth of 10-15 m for 12-14 months to measure the diversity and community composition of macroinvertebrates within and among sites. 3 sites were used per region, with 3 replicates per site. We identified invertebrates to the class level using traditional taxonomy, and used COI metabarcoding to identify to the lowest possible level. We compared community composition and diversity metrics using both kinds of data. All seas were significantly different in composition, though metabarcoding provided stronger separation among groups than traditional taxonomy. The Black Sea showed notably low diversity relative to other seas using both data types. Although metabarcoding of ASUs allowed for robust comparisons of community composition, comparisons with taxonomy showed that not all groups were sequenced successfully (e.g. mussels). The use of both methods in conjunction is therefore currently a better technique for marine monitoring of these groups than either of them separately when using ASUs.

8.2 CALHOUN, SM*; ZOU, E; Nicholls State University, Thibodaux, LA; *scalhoun1@its.nicholls.edu*

Correlation Between Epidermal Carbonic Anhydrase and Exoskeletal Metals Content in the Blue Crab, Callinectes sapidus

During the crustacean molting cycle, the exoskeleton is first mineralized in postmolt and intermolt and then presumably demineralized in premolt in order for epidermal retraction to occur. Mineralization requires divalent metal ions, such as Ca^{2+} and Mg^{2+}, and bicarbonate ions whereas protons are necessary for dissolution of carbonate salts. Carbonic anhydrase (CA) has been suggested to be involved in exoskeletal mineralization by providing bicarbonate ions through catalyzing the reaction of carbon dioxide hydration. However, results of earlier studies on the role of epidermal CA in metal incorporation in crustacean exoskeleton are not consistent. This study was aimed to provide further evidence to support the notion that epidermal CA is involved in exoskeletal mineralization using the blue crab, *Callinectes sapidus*, as the model crustacean. Significant increases in first calcium, then magnesium and manganese post-ecdysis indicate significant metal deposition during postmolt and intermolt. Significant positive correlation between calcium or magnesium content and epidermal CA activity in postmolt and intermolt constitutes evidence that CA is involved in the mineralization of the crustacean exoskeleton. Herein, a hypothetical model is proposed to describe the role of epidermal CA in both mineralization and demineralization of the exoskeleton based on the results of this study. Furthermore, we found that the pattern of epidermal CA activity during the molting cycle of *C. sapidus* is similar to that of ecdysteroids reported for the same species, suggesting that epidermal CA activity may be under control of the molting hormones.

96.1 CALISI, RM*; CAI, F; University of California, Davis, Columbia University; *rmcalisi@ucdavis.edu*

Seasons and Neighborhoods of High Lead Toxicity in New York City: the Feral Pigeon as a Bioindicator

Although U.S. government bans on lead in paint and gasoline have significantly reduced lead concentrations in human tissues, lead is still prevalent in our environment. Lead can have detrimental effects on a variety of body processes and is particularly harmful to the developing nervous system, causing potentially permanent health, learning and behavioral disorders. Previous studies outside of the United States have had success using the feral pigeon as a bioindicator to measure heavy metal prevalence in cities. However, none have been conducted in the U.S. or have examined the important effects of season on their blood lead levels. Also, to our knowledge, none have investigated whether a link exists between pigeon blood lead levels and rates of child blood lead toxicity. We collected blood lead level records from 825 pigeons representing various NYC neighborhoods over the four seasons between the years of 2010 and 2015. We found blood lead levels varied by season in the same way that they do in children. We also found that neighborhoods producing pigeons with the highest blood lead levels also exhibited some of the highest rates of lead in children identified by the NYC Department of Health and Mental Hygiene. Thus, we provide support for the use of the feral pigeon as a bioindicator of blood lead levels for the first time in the U.S. and for the first time anywhere in direct association with rates of elevated blood lead levels in children.

S2.2 CALSBEEK, Ryan; Dartmouth College; *ryan.calsbeek@dartmouth.edu*

Metamorphosis and the resolution of ontogenetic conflict

Life-history theory is a cornerstone of modern evolutionary biology that addresses myriad phenomena ranging from demography and population structure to the evolution of ageing and senescence. Trade-offs may arise in a number of contexts, from allocation-based (e.g., egg size versus egg number) to genomic conflicts (e.g., intralocus sexual conflict in which genes that perform well in males perform poorly in females). Here I examine locomotor performance tradeoffs in human triathletes and show that swimming performance trades off with running and cycling performance. The tradeoff is plastic and trained versus untrained athletes experience the tradeoff differently. I use these patterns to motivate a study of performance tradeoffs in a natural wood frog system. Frogs experience both aquatic and terrestrial life stages over the course of their life history. However, "adaptive decoupling" of the life stages during metamorphosis may resolve the ontogenetic conflict that would otherwise constrain frogs to perform well either as tadpoles or as adults.

P1.205 CAMP, AL*; ASTLEY, HC; HORNER, AM; ROBERTS, TJ; BRAINERD, EL; Brown University, Univ. of Akron, California State University, San Bernardino; *ariel.l.camp@gmail.com*

Fluoromicrometry: using X-ray video to measure the in vivo muscle dynamics of animal behaviors

Muscles produce an amazing range of animal movements, and much of their function as biological motors depends on how much—and how fast—they change in length. Hence, measurements of in vivo muscle length changes are essential for understanding the mechanisms of muscle-powered motion. We describe the methods and validation of fluoromicrometry, a technique for measuring muscle length using biplanar X-ray videos. Small (0.5-0.8 mm), radio-opaque markers are surgically implanted into a muscle, and the freely-moving animal is recorded with biplanar fluoroscopy. The 3D position of each marker is calculated from the X-ray videos (using free XROMM software), and the change in distance between adjacent markers used to measure muscle length throughout the behavior. We have measured the precision of fluoromicrometry to be 0.09 mm, and confirmed that it is accurate, with no significant bias in the resulting length measurements. Fluoromicrometry has been used to study several animals and behaviors including axial muscles in feeding fish, the plantaris muscle in jumping frogs, and hind-limb muscles in walking rats. Fluoromicrometry allows for wireless data collection, a large number of intramuscular markers, the potential for long-term implantation, and 3D position and motion data for each marker. It can be collected synchronously with X-Ray based skeletal kinematics (XROMM) to examine the interaction of muscle and bone motion, and in particular the contribution of muscle and tendon to the overall length of muscle-tendon units. While it is limited by the small imaging volume and accessibility of biplanar X-ray filming, fluoromicrometry provides an exciting new tool for investigating musculoskeletal biomechanics.

140.2 CAMP, AL*; ROBERTS, TJ; BRAINERD, EL; Brown University; *ariel.l.camp@gmail.com*

A little mouth with a lot of power: how cranial and axial muscles generate suction expansion in bluegill sunfish

Ray-finned fishes exhibit tremendous variation in their mouth-size and body-shape, yet most capture food by suction feeding. In one species, largemouth bass, the power for suction expansion comes almost exclusively from the body muscles, as even the largest of the cranial expansion muscles, the sternohyoideus, produces negligible power. However, it is unclear if axial muscles power suction feeding in most fishes, or if this is limited to bass-like fish with large mouths, fusiform bodies, and a relatively small sternohyoideus muscle. Bluegill sunfish (*Lepomis macrochirus*) are a good test-case, as they are in the same family as largemouth bass (Centrarchidae), but have a small mouth, a tall and laterally-compressed body, and a relatively large sternohyoideus muscle. To determine the role of axial muscles during suction expansion in sunfish, we measured in vivo muscle shortening and skeletal kinematics using fluoromicrometry and X-Ray Reconstruction of Moving Morphology (XROMM). In sunfish, the epaxial muscles shortened to elevate the neurocranium and the hypaxial muscles shortened to retract the pectoral girdle during suction feeding. Like largemouth bass, sunfish used large regions of their axial muscles, extending nearly halfway down the body, to generate power during suction feeding. However, in sunfish the sternohyoideus muscle also shortened and contributed power to suction feeding, whereas it functions like a ligament in largemouth bass. These results highlight the multiple roles of the sternohyoideus in suction feeding, and suggest that the relatively powerful strikes of sunfish (compared to their body size) may require both cranial and axial muscle power.

P2.204 CAMPBELL, A. M.*; KORZENIECKI, N. W.; WATERS, J. S.; Providence College; *acampbe5@friars.providence.edu*

The Ants of Rhode Island: Species Richness and Spatiotemporal Abundance of Ants Across an Urban College Campus

Compared to the rest of New England, relatively little is known about the biodiversity of ants in Rhode Island. The sampling has been especially sparse in the county of Providence. To understand more about the species richness and natural history of our home state, we conducted a series of sampling studies to collect and identify the ants on campus at Providence College, and more widely in the region. The first systematic survey involved a longitudinal ten-week pitfall trap collection method. The follow-up surveys involved general collecting, baiting, and leaf-litter sifting. Ants were preserved and sorted in ethanol and select specimens pinned for identification using morphological characteristics, focus-stacked macrophotography, and scientific illustration. Nearly two thousand ants were identified to more than 20 species from four subfamilies: including Ponerinae, Dolichoderinae, Formicinae, and Myrmicinae. We also report the first record in New England, a singleton, of *Brachyponera chinensis*, an invasive ant previously only collected as far north as New York.

P2.249 CAMPBELL, JB*; HARRISON, JF; Arizona State University; *jacob.campbell.1@asu.edu*
Variation in anoxia tolerance is not explained by the maintenance of ATP in Drosophila melanogaster
Many insect life stages have the potential to be exposed to hypoxia or even anoxia. Insects generally are much better at surviving anoxia than vertebrates, at least partly because the tracheal system permits restoration of tissue oxygen by diffusion. Surprisingly, we still lack a fundamental understanding of how anoxia kills and the mechanisms responsible for variation among species and developmental stages. Anoxia-tolerant vertebrates are able to maintain ATP levels during anoxia through a coordinated reduction in metabolism and/or elevated anaerobic metabolism. Here we tested whether maintenance of ATP can explain variation in anoxia-tolerance across *Drosophila melanogaster* strains and developmental stages. Adults survive anoxic durations much longer than larvae, anoxia tolerance decreases with adult age, and Drosophila Genetics Reference Panel lines exhibit 4-fold variation in anoxia tolerance. ATP declines to ~5% of resting within 30 min for adults and within 60 min for larvae, well before the time mortality begins to occur, suggesting loss of ATP does not immediately cause death. Similarly, preservation of ATP levels was not correlated with anoxia tolerance across development stages, age or genetic strain. As the primary hypothesis for variation in anoxia-tolerance in vertebrates was rejected, we conducted a GWAS to identify candidate genes responsible for variation in anoxia survival using the Drosophila Genetics Reference Panel. Survival of 1 hr of anoxia in 178 lines from the DGRP ranged from 25-95%; 23 genes were associated with variation in survival. Several of the identified genes have human orthologs that have been linked to oxygen-related pathologies in humans, as well as mechanisms involving immune function and general stress response. In insects, variation in anoxia tolerance seems to occur due to variation in the ability to cope with depleted ATP levels. Supported by NSF IOS 1256745.

5.3 CAMPBELL STATON, SC*; WINCHELL, KM; University of Illinois, Champaign-Urbana, University of Massachusetts, Boston; *shane.campbellstaton@gmail.com*
Urban heat islands and temperature-mediated physiological shifts between populations of the Puerto Rican crested anole
Urbanization creates local environments that are hotter than surrounding natural areas. Urban warming likely has widespread biological consequences, affecting temporal patterns of growth, survival and reproduction. Therefore urban heat islands may provide insights into thermal adaptation and evolution. We explore the evolution and divergence of thermal tolerance between urban and natural populations of the crested anole across the island of Puerto Rico. We hypothesize that ectotherms from warm, urban environments should tolerate heat better and cold worse than ectotherms from cooler natural environments. To test our predictions, we will compare the thermal tolerance of crested anoles (Anolis cristatellus) from populations in urban environments and nearby forests. Ongoing research is using functional genomics to identify specific regulatory pathways associated with thermal tolerance under hot and cold conditions, respectively and search for signatures of selection on thermal tolerance in urban environments.

64.2 CAPANO, JG*; MORITZ, S; BRAINERD, EL; Brown University; *john_capano@brown.edu*
Comparison of 3D rib kinematics during breathing in the Argentine black and white tegu, Salvator merianae, and green iguana, Iguana iguana
Costal aspiration, in which rib movements ventilate the lungs, is a complex combination of 3D rib rotations where each rib can theoretically rotate about three axes: bucket-handle about a dorsoventral axis, caliper about a craniocaudal axis, and pump-handle about a mediolateral axis. The objective of this study is to understand rib kinematics during breathing in the Argentine black and white tegu, *Salvator merianae*, and compare them to those of the green iguana, *Iguana iguana*. Tegu thoracic ribs have three mineralized segments: vertebral, intermediate, and sternal, whereas iguanas have vertebral and sternal. Tegu costovertebral articulations are dorsoventrally elongated and hemiellipsoidal, while those of iguana are hemispherical. We implanted radio-opaque markers into the three rib segments of three tegus and used marker based XROMM to quantify the rotations. We found motion between vertebral and sternal segments but negligible motion between vertebral and intermediate segments, indicating that tegu ribs are functionally bipartite during breathing. Similar to iguanas, tegu vertebral rib rotations were predominantly bucket-handle, but tegus showed significantly less caliper motion, suggesting that the hemiellipsoidal costovertebral articulations constrain motion of the vertebral ribs. Tegu sternal ribs displayed similar magnitudes of bucket and pump-handle motion but the sternocostal joint anatomy suggests no dominant axis of rotation. We used helical axis analysis to describe these rotations and show that the sternal ribs act like a hinge joint through most of their motion. Overall, tegus and iguanas display similar rib rotations, which suggests that bucket-handle rotation may be widespread in squamates, despite variations in rib morphology.

S8.10 CAREAU, V*; WILSON, R.S.; University of Ottawa, The University of Queensland; *vcareau@uottawa.ca*
Detecting Performance Trade-offs Using Multivariate Mixed Models
All of us routinely experience performance trade-offs as we complete various tasks. For example, the faster we write, the more likely we are to make mistakes! Therefore, if we look across all 2017 SICB abstracts we could expect a negative correlation between the time spent writing an abstract and the number of mistakes it contains. However, we can also predict a positive correlation because SICB members greatly vary in their writing skills (i.e., some of us are "Darwinian demons" and are able to quickly write excellent error-free abstracts). This situation is similar to the classic "big house big car" model of life-history evolution where individuals differ in their ability to acquire resources, but nevertheless have to allocate their resources into current vs. reproduction. In this case, phenotypic correlations among life-history traits can be either positive, negative, or nil depending on whether there is respectively more, less, or equal variance in acquisition and allocation among vs. within individuals. This is one of the main reason why performance and life-history trade-offs can be hard to detect at the phenotypic level. In this talk, we show how multivariate mixed models (MMMs) can help understand performance (or any other type of) trade-offs. Indeed, MMMs allow straightforward and simultaneous examination of trait correlations at several levels of variation (e.g., within and among individuals, populations, or species, etc.). It is now relatively easy to run MMMs using softwares like R, SAS, WOMBAT, ASReml, and others, yet MMMs are underused in performance studies. We will use a few published datasets in which several individuals were repeatedly sampled for multiple performance traits to illustrate what insights can be gained by applying MMMs to detect performance trade-offs (e.g., speed vs. accuracy).

S5.5 CAREY, Hannah V.*; ASSADI-PORTER, Fariba M.; Univ. of Wisconsin-Madison; *hannah.carey@wisc.edu*
Seasonal remodeling of the host-microbe symbiosis in hibernation
Bacteria resident in vertebrate guts expand their hosts' metabolic capabilities and modulate development, immunology and diverse physiological functions. Hibernation is a unique system to understand the interplay among host biology, diet and microbiota in mammals because extended winter fasting eliminates a major source of substrates for bacterial metabolism, with potential effects on symbiotic interactions. The annual hibernation cycle reconfigures microbiota composition in 13-lined ground squirrels, increasing relative abundance of taxa that can degrade host-derived substrates and reducing abundance of taxa that prefer plant glycans. The intestinal immune system, the host's primary sensor of gut microbiota, is also remodeled during winter fasting. We use stable isotope-assisted breath analysis and antibiotic manipulation to examine how seasonal changes in microbiota composition influence function in vivo, and affect host characteristics that are associated with microbial activity. Active season squirrels and aroused hibernators were gavaged with ^{13}C-labeled substrates including inulin, a complex plant-derived fiber, and mannitol, a simple sugar alcohol, neither of which are metabolized by mammalian enzymes; the ratio of $^{13}CO_2$ /$^{12}CO_2$ in breath reflects bacterial substrate degradation in vivo. Hibernation progressively reduces bacterial capacity to degrade ^{13}C-inulin, whereas breath responses to ^{13}C-mannitol are unaffected. Antibiotic manipulations alter host immune and epithelial features and increase visceral fat in summer squirrels. These studies confirm strong effects of hibernation on microbiota function in vivo and suggest a potential role for gut symbionts in hibernation physiology.

P2.236 CAREY, N*; GOLDBOGEN, JA; Stanford University, Hopkins Marine Station; *ncarey@stanford.edu*
Life's a Drag: Comparative kinematics of swimming modes in anchovies and sardines
Forage fish, pelagic schooling fish such as sardines and anchovies, are a vital node in 'wasp waist' food webs, linking lower and higher trophic levels, and are the main food source for a diverse assemblage of predators. Forage fish such as the anchovy, *Engraulis mordax*, and Pacific sardine, *Sardinops sagax*, exploit a variety of feeding strategies, with differing energetic consequences. At large relative prey size, they capture by biting, but when prey are small they employ ram filter feeding. Under filter feeding, the mouth is kept wide open, greatly increasing drag in the ultra-dense aquatic environment. These fish switch from highly streamlined, efficient swimming, to highly non-hydrodynamic, energetically costly swimming depending on the food available. A major consideration however, is that school integrity is maintained, a vital strategy against most predators, and so body kinematics must change between swimming modes to maintain speed. We examine the biomechanical challenges of maintaining swimming speed under extremely low and extremely high drag in E. mordax and S. sagax. Using high-speed video, we present detailed kinematic analyses of three swimming modes in these sympatric species; ram, stroke-and-glide and fast escapes. We present data on both behavior in the school, and also detailed midline kinematics of individuals. The dynamics of sardine and anchovy populations follow long-scale, 'boom-bust' fluctuations, particularly in the eastern Pacific, which are still not fully understood, but likely include the effects of climate. Based on our analyses, we predict that the energetic consequences of ram filter feeding may also play an important role in the foraging efficiency and fitness of forage fish in different environmental regimes.

65.7 CARLO, MA*; SEARS, MW; Clemson University; *mcarlo@clemson.edu*
Eastern fence lizards (Sceloporus undulatus) exhibit inter-annual nest site fidelity and intra-annual variation in nest site selection
One of the most important decisions an oviparous mother can make is where to put her nest. This decision determines the environmental conditions experienced by developing embryos. For instance, Eastern fence lizards (*Sceloporus undulatus*) lay their eggs in shallow underground nests, where embryos are exposed to daily temperature fluctuations due to heat flux from the soil surface. Research on nesting behavior suggests *S. undulatus* females will travel long distances beyond their home ranges to nest in the warmest parts of the environment. Yet, rapid climate change is pushing conditions at those nest sites toward the physiological limits of developing embryos. Therefore, variation in nesting behavior could increase the potential for population persistence under warming conditions if fence lizards can also select cooler nest sites (shadier or deeper, e.g.). In 2015 and 2016, we conducted field research to examine nesting behavior in a *S. undulatus* population in South Carolina. We tracked gravid females using radio telemetry to locate nest sites and compare habitat use during the summer breeding season. Results showed lizards revisit nest sites annually, while exhibiting variation in nest site selection between clutches in the same season. Females traveled significantly greater distances and selected warmer, sunnier nest sites to lay their second clutches, compared to their first. Individual variation in nesting behavior could be advantageous to the population if alternative nest sites buffer offspring from the deleterious effects of rapid warming. In addition, variation in the thermal environment among nest sites within seasons could enable evolution of thermal physiology and persistence of the species under rapid climate change. Although, more research is needed to determine whether evolution rapid enough to keep pace with climate change is possible.

P3.204 CARLOWICZ, R*; MORAN, C/J; GERRY, S/P; Fairfield University; *Rachel.Carlowicz@student.fairfield.edu*
Variation in Feeding Behavior in Polyphenic Bluegill
Polyphenic populations are a valuable resource for understanding the relationship between form and function. Morphological variation within a population can have dramatic impacts on performance and subsequently fitness. In Lake Waban (Wellesley, MA), bluegill *Lepomis macrochirus* have diverged into two ecomorphs, which occupy pelagic and littoral habitats. Based on morphological variation of the oral jaws and diet studies, we hypothesized that littoral individuals would use more suction during feeding than pelagic fish. To address this hypothesis, we measured pressure and kinematics during prey capture on earthworms, mealworms and brine shrimp. We found that littoral fish used more suction when feeding on all prey types and varied their feeding behaviors depending on prey type. Similarly, the littoral ecomorph traveled a greater distance during feeding, suggesting that they use more ram than the pelagic fish. Pelagic bluegills exhibited a stereotyped feeding behavior for all prey types, which suggests that they have reduced modularity during feeding. These results give further credence to the divergence in behavior and morphology that is seen when comparing two phenotypes of bluegill. The stereotyped behavior reflects previous work on cichlids which are pelagic prey specialists. The results from our study suggest that pelagic bluegills undergo a behavioral shift that allows them to specialize on pelagic prey. Conversely, littoral fish maintain a varied diet which allows them to feed on a variety of prey items.

P2.25 CARR, GM*; PODOLSKY, RD; Northwestern University, College of Charleston; *gabrielacarr2017@u.northwestern.edu*
Effects of elevated CO_2 on encapsulated development in 14 gastropod species
Ocean acidification (OA) resulting from elevated CO_2 is posing a worldwide threat to marine organisms, in part by interfering with the production of shells and other calcified structures. It is increasingly important to identify characteristics of organisms that make them susceptible or resilient to pH change. Species from taxa including gastropods, crustaceans, polychaetes, and fishes spend part of their early development inside encapsulating structures. Such structures are of special interest with regard to OA because (1) they could help to buffer against low pH as they have been shown to do for other environmental risks, and (2) embryos that develop inside such structures may have been selected to withstand the pH decline resulting from their own respiratory CO_2 production. We tested the effect of elevated CO_2 on hatchling shell size, inorganic and organic content, and development rate in 14 gastropod species with different types of encapsulating structures. We found mostly moderate differences in response to low (600 ppm), medium (1050 ppm), and high (1500 ppm) CO_2 concentrations across all species taken as a whole. In a few cases we found a decline in shell length, though without a corresponding decline in inorganic content, suggesting that while calcification was generally resilient to elevated CO_2, the morphology of certain shells might have been affected. Development rate decreased in several species and overall among all species, indicating that developmental processes were sensitive to elevated CO_2. Species with string-type egg masses appeared particularly sensitive. Our results suggest that encapsulated embryos tend to be resilient to low pH and other effects of CO_2, and that designs of some encapsulating structures may contribute to this resilience more than others. Such effects could have implications for future differences between species persistence in the face of increasing OA.

130.3 CARR, JA*; ANKARALI, MM; DANOS, N; COWAN, NJ; TYTELL, ED; Tufts Univ., Middle East Technical Univ., Univ. of San Diego, Johns Hopkins Univ.; *jennifer.carr@tufts.edu*
Noisy work loops: A new technique for understanding how muscle intrinsic properties contribute to the non-steady dynamics of rhythmic movements
Intrinsic muscle properties, such as dependence of force on length and velocity, have been hypothesized to help organisms to respond to destabilizing conditions predictably and rapidly, but relatively few experiments have tested this hypothesis in a quantitative way. These stabilizing (or destabilizing) effects are particularly challenging to understand during rhythmic muscle activity, and most behavior involves rhythmic motion. Our study uses a modified work loop protocol to measure how muscle in the silver lamprey, *Ichthyomyzon unicuspis*, responds to perturbations during swimming. We use these data to develop a model to predict the muscle function. A section of axial musculature was dissected and used to perform standard in vitro work loops. A baseline sinusoidal length change was imposed on the muscle and force was measured. To examine the effects of muscle activation, the muscle was stimulated at different phases during the cycle. Next, we added a pseudorandom stimulus composed of sums of small sinusoidal perturbations at multiple frequencies to the baseline oscillation. Using a new system identification technique based on harmonic transfer functions, we can characterize how the muscle responds to the perturbations and how the response depends on the phase of the baseline oscillation. The model makes testable predictions about how the muscle would respond to any small perturbation at any phase. Preliminary results indicate that both the effective stiffness and damping properties of the muscle change within a cycle. Moreover, these properties differ for muscle depending on the phase during the length-shortening cycle when the muscle is activated.

P3.111 CARRELL, S/C*; DAVIS, J/E; Radford University, Radford; *scarrell2@radford.edu*
The Effects of Juvenile Hormone (JH) on the Social Behavior of Leucauge venusta, the Orchard Orbweaver, and Araneus diadematus, the Cross Orbweaver
Various species of spiders have been generally labeled as being simply social or asocial. In reality, there is a large range of variation and substantial multidimensionality across spider social behavior. Our goal in this study was to explore the biochemical influences that may regulate sociality in spiders. In doing so, two different female species, both semi-social yet distantly related, were tested to explore variations in modulation of sociality. *Leucauge venusta*, the Orchard orbweaver, and *Araneus diadematus*, Cross orbweaver, were used as model species since both species have previously been shown to display clustering behavior under certain circumstances and at different life stages. We specifically hypothesized that sociality would be influenced by exposure to Juvenile Hormone (JH). JH has been shown to play a central role in the modulation of both behavior and physical development in invertebrates. Specifically, elevated JH has been shown to maintain juvenile morphological features as the organism develops; when JH drops invertebrates molt into their adult form and become reproductively active. In turn, we believe JH may also play a central role in regulation of social tolerance; given that juvenile spiders exhibit increased social tolerance and JH maintains juvenile physiology, it is likely that increased levels of JH may result in the maintenance of juvenile-form social tolerance into adulthood. To test this, 12 spiders of each species were dosed with either methoprene (a JH agonist) or a control treatment every other day for 15 days. During this time, we measured the distance between spiders, their distribution within the housing environment and features of their web placement. Here we will discuss outcomes of this study and the possible relationship to the evolution of spiders and sociality in general.

35.2 CARRILLO, A*; BYRON, ML ; MCHENRY, MJ; Univ. of California, Irvine; *an.carrillo@yahoo.com*
Sensing prey in the dark improves with age in zebrafish
Fish forage in the dark by using the lateral line system to detect water flow generated by prey. Upon hatching, the lateral line includes one type of receptor, the superficial neuromast (SN), and this is joined by a second type, the canal neuromast (CN), by the time a fish has grown into an adult. Although CNs are known to have superior sensitivity to high-frequency stimuli, it is unclear if their development endows a fish with a superior ability to forage in the dark. We investigated this subject by comparing foraging behavior in darkness in zebrafish (*Danio rerio*) at 30 day-post-fertilization (dpf), which have only SNs and at 90-dpf fish, which have both receptor types. In order to examine the flow regimes that stimulates feeding at these stages, we found that we could provoke feeding in the dark with a vibrating sphere over a range of frequencies. Sphere detection was determined by unconditioned eye motion directed at the sphere. By this measure, the older fish sensed the sphere at about twice the distance of the younger fish. Therefore, the development of of CNs is correlated with enhanced flow sensitivity. Therefore, the development of receptors in the lateral line system appears to equip fish with the ability to exploit habitats with limited or no light.

49.1 CARRINGTON, E*; GEORGE, M; HAYFORD, H; NEWCOMB, L; FRIEDMAN, C; JEFFERDS, I; University of Washington , Penn Cove Shellfish LLC; *ecarring@uw.edu*

All washed up? Mussel survival in the face of ocean warming and acidification

Bivalve mussels are foundational species on many temperate coasts, dominating and structuring mid-intertidal zones. They are also important aquaculture species, sustaining a worldwide industry worth over $1.5 billion annually. The key to the mussel's success is its ability to anchor to rocks and culture ropes with bungee-like fibers (byssal threads) which dynamically absorb wave energy. Weak attachment leads to mussel dislodgment (fall-off) and ultimately mussel death. Work from our laboratory on *Mytilus trossulus* has shown mussel byssal thread quality and quantity is lowered by ocean acidification (OA) and warming (OW), weakening overall attachment strength up to 40-80%, respectively. We used our previous biomechanical model for *Mytilus edulis* in Narragansett Bay, RI to predict how mussel dislodgment would be altered under different "climate-driven" weakening scenarios. Results indicate a nonlinear effect, where small (0-20%) reductions in attachment strength have little impact (80-70%) on annual survival. Large reductions in strength, those expected with OA and/or OW, will reduce mussel survival to 10-60%, levels that may not be ecologically or economically viable. We have also shown attachment responses to OA and OW differs among congener mussel species, and this ecomechanical approach is a useful tool for predicting relative performance of species under different growing conditions, in farmed and natural settings.

P2.30 CARTER, AL*; BODENSTEINER, BL; IVERSON, JB; MILNE-ZELMAN, CL; MITCHELL, TS; REFSNIDER, JM; WARNER, DA; JANZEN, FJ; Iowa State University, Ames, Earlham College, Richmond, IN, Aurora University, IL, Auburn University, AL, University of Toledo, OH; *acarter1@iastate.edu*

Modeling the Incubation Microclimate to Predict Implications of Responses to Climate Change for a Thermally-mediated Trait

A key aim of ecology is understanding how populations respond to environmental variation, especially rapid climate warming. While climate change is typically modeled on a continental or global scale, responses depend on complex physiology-microenvironment interactions that manifest at both population and individual levels. In species with temperature-dependent sex determination (TSD), temperature variation may dramatically skew offspring sex ratios, reducing population viability. However, predictive models that rely on broad-scale climate data do not capture the microclimate-scale processes that drive thermally-mediated embryonic development. We used a spatially-explicit model of embryonic development, driven by a mechanistic soil temperature model, to examine the microclimate-mediated consequences of hypothetical behavioral and physiological responses to climate warming in painted turtles (*Chrysemys picta*), a widespread species with TSD. Shifts in thermal reaction norms, due to modifications of either maternal behavior (nesting phenology and/or nest location and depth) or temperature-dependent developmental parameters, could buffer offspring sex ratios against climate change. However, effectiveness of either strategy is mediated locally by the rate of response(s) and magnitude of climate warming observed.

99.5 CARTER, CB*; COOPER , WJ; SMITH, A; RICE, AN; WESTNEAT, MW; Washington State University, University of Massachusetts, Amherst, Cornell University, University of Chicago; *casey_carter@wsu.edu*

The evolution of jaw protrusion mechanics is tightly linked to ecological divergence along a bentho-pelagic niche axis in damselfishes (Pomacentridae).

Jaw protrusion is one of the more remarkable functional abilities to have evolved among fishes. We sought to determine if changes in protrusion mechanics are tightly linked to divergence along one of the most important ecological axes in aquatic systems: the bentho-pelagic axis. We examined skull morphology and feeding kinematics in the damselfishes, which constitute a highly-successful radiation of marine fishes that have undergone repeated convergence on three ecological states: planktivory (pelagic feeding), a limited form of omnivory (bentho-pelagic feeding) and herbivory (benthic feeding). The ten species examined included multiple examples of convergence on all three of these feeding niches. Using phylogenetic comparative analyses of both skull shape and kinematic data we determined that: 1) planktivorous damselfishes have significant differences in jaw protrusion ability relative to members of the other trophic guilds; 2) jaw protrusion ability has evolved in correlation with a suite of additional morphological and functional traits associated with feeding; 3) pomacentrids capable of extensive protrusion exhibit higher levels of functional integration between upper and lower jaw movement than other species and 4) the best-supported evolutionary model for the diversification of damselfish feeding mechanics indicates that their repeated ecological convergence has been accompanied by morphological and kinematic convergence on three adaptive peaks. The evolution of jaw protrusion has been tightly linked to bentho-pelagic divergence in damselfishes and the evolution of their trophic morphology has involved repeated convergence in form, function and ecology.

38.1 CARTER, AW*; TUBERVILLE, TD; PAITZ, RT; BOWDEN, RM; Illinois State University, University of Georgia; *amandawilson1213@gmail.com*

Are heat waves key to understanding TSD in nature?

Most turtles possess temperature-dependent sex determination where eggs incubating above a threshold temperature (pivotal temperature; Tpiv) develop as females and eggs incubating below the Tpiv develop as males. Despite inhabiting broad geographic ranges, turtles have a similar Tpiv across species and populations (~29°C), making the production of both sexes in different climates enigmatic. To help resolve how TSD operates naturally, we hypothesized that populations vary in "thermal responsiveness," a novel trait defined as the amount of thermal exposure (an interaction of time and magnitude above the Tpiv) necessary to trigger female development. Functionally, this would result in populations and species differing in the duration of exposure to temperatures above the Tpiv (i.e. heat waves) necessary to induce the production of females, and would not necessitate variation in the Tpiv itself. We predict that northern populations will be more "thermally responsive," requiring shorter heat waves to produce females than southern populations. To test this, *Trachemys scripta* eggs were collected from LA, SC, and IL, and incubated under daily fluctuating temperatures (27±3°C) known to produce only males. After 20 days of incubation, eggs were switched to a female producing condition (29.5±3°C) for variable durations (0-30 d). This incubation schema allows us to determine how much exposure to warm conditions is required to shift sex from male to female, and whether the amount of exposure to warm conditions required to produce females differs across populations. Variation in "thermal responsiveness" should help explain how populations and species produce mixed sex ratios naturally, despite possessing similar Tpiv's.

P1.250 CARTER, AM*; DODSON, P; HSIEH, ST; University of Pennsylvania, Temple University; *Caja@sas.upenn.edu*

Vertebral function in obstacle crossing behaviors in Polypterus senegalus

Amphibious fishes are surprisingly diverse and can serve as excellent models for understanding locomotor challenges of relevance to early tetrapods and basal amphibians. While studies of amphibious fishes moving across flat surfaces have revealed diverse behaviors and techniques enabling terrestrial locomotion, still little is known about how they move across complex terrain. The bichir is an elongate fish that moves on land using a combination of stepping with the pectoral fins and lateral body undulations, and proposed to be similar to how early tetrapods moved on land. In this study, we quantified how Senegalese bichirs (Polypterus senegalus) co-opt basic lateral bending for more complicated tasks, such as obstacle crossing. We filmed individuals with high-speed cameras (Photron SA-3) at 250 fps as they moved over obstacles of different heights (1-5mm), and quantified pectoral fin placement and head and body posture and elevation. Several key characteristics were identified that facilitated successful obstacle crossing: (1) bichirs adjusted nose elevation to match the obstacle height; (2) fish appeared to use a combination of skull pitch and roll to increase head elevation, rather than pure dorsal flexion; and (3) pectoral fin placement relative to the obstacle was of critical importance. When the fins were planted more than 3cm from the obstacle, the bichirs failed to cross, regardless of the amount of head elevation. The fact that pectoral fin placement was such an important determinant of obstacle crossing demonstrates how being able to coordinate axial and appendicular movements for moving across complex terrain may have been a critical step in the evolution of terrestriality among early tetrapods.

111.1 CARTER, W.*; COOPER-MULLIN, C.; MCWILLIAMS, S.R.; University of Rhode Island; *wales.carter@outlook.com*

Turnover of Muscle Lipids and Response to Exercise Differ between Neutral and Polar Fractions in a Model Songbird

The turnover rates of tissues and their constituent molecules give us insights into animals' physiological demands and their functional flexibility over time. Thus far, most studies of this kind have focused on protein turnover, but, few have considered lipid turnover despite an increasing appreciation of the functional diversity of this class of molecules. Given the particular importance of lipids as a fuel source for birds, we measured the turnover rates of neutral and polar lipids from the pectoralis muscles of a model songbird, the Zebra Finch (*Taeniopygia guttata*, N=65), in a 256 day C_3/C_4 diet shift experiment, with tissue samples taken at ten time points. We also manipulated the physiological state of a subset of these birds with a 10 week flight training regimen to test the effect of exercise on lipid turnover. We measured lipid $\delta^{13}C$ values via IRMS and estimated turnover in different fractions and treatment groups with nonlinear mixed effect regression. We found a significant difference between the mean retention times of neutral and polar lipids (t_{195}=-2.22, P=0.028), with polar lipids (τ=11.80±1.28 days) having shorter retention times than neutral lipids (τ=19.47±3.22 days). We also found a significant decrease in the mean retention time of polar lipids in exercised birds relative to control birds (difference = -4.34±1.83 days, t_{56}=-2.37, P=0.021), but not neutral lipids (difference = 4.22±7.41 days, t_{56}=0.57, P=0.57). The position of polar lipids in cell and organelle membranes, particularly mitochondria, may make them more susceptible to damage from reactive species and the increased metabolic rates associated with exercise likely increase the production of these species, thus providing a mechanism consistent with our results.

P1.13 CARY, TL*; WIENHOLD, C; BRANCHAW, JL; University of Wisconsin-Madison; *caryt@beloit.edu*

Development and validation of the Five Core Concept Instrument (5CCI) to measure student conceptual understanding in biology

The Vision and Change report (AAAS, 2011) recommends that biology educators structure undergraduate teaching around five core concepts to support student development of a cognitive framework for learning biology. However, validated instruments to assess student conceptual understanding of the proposed core concepts do not exist. Using a framework of conceptual elements that transcend biological scale for each core concept, we developed and validated a comprehensive assessment instrument, the five core concept instrument (5CCI). The 5CCI assesses students' ability to generate, in writing, their own understanding of a core concept, identify concepts within biological phenomena, and make connections between concepts. To objectively score the student-generated responses, we developed an associated rubric and a novel component scoring system that discriminates a student's ability to apply and identify each core concept addressed in the narrative from their ability to make connections between core concepts. We field-tested the 5CCI with students at the beginning of their Introductory Biology I course and at the end of their Introductory Biology II course (N = 358) to measure whether their performance was affected following two semesters of general biology. Students improved their ability to answer true/false statements accurately and identify core concepts; however, some concepts, like Pathways and transformations of energy and matter, remained challenging for students even after completing two semesters of biology. Our results demonstrate the utility of the 5CCI as a validated instrument with the unique feature of component scoring to allow bioscience educators to assess nuanced understanding of the Vision and Change core concepts across biological phenomena.

107.6 CASTEEL, Z/C; HEDRICK, B*; PODOS, J; Univ. of Massachusetts, Amherst ; *z.c.casteel@gmail.com*

The Sound of Shape: Subtle aspects of subspecific variation in the highly polytypic Song Sparrow

Melospiza melodia is highly polytypic and one of the most highly accomplished emberizid singers, hence its common name, the Song Sparrow. *M. melodia* is phylogenetically diverse, with a large number of subspecies and a range that encompasses much of North America. We examine subspecific variation in beak shape of *M. melodia* using geometric morphometrics and we utilize a recently developed metric, frequency excursion (FEX) to measure song performance. Covariation in beak shape and song performance has previously been found in *Geospiza*, and beak shape may constrain song production in *Melospiza* as well. Geometric morphometric analyses were carried out on specimens from 9 subspecies, representing birds from the Northeast, Southwest, Mexican plateau, Pacific Northwest, California, and Alaskan regions of North America. Two additional *Melospiza*. species, *M. georgiana* and *M. lincolnii*, were included in the analyses as outgroups to examine interspecific variation. Our results demonstrate statistically significant differences in beak shape within *M. melodia*. Species that are farther separated geographically tend to have more highly disparate shapes, in some cases similar in magnitude to interspecific differences within *Melospiza*. The song performance aspect of our study uses FEX, which uses the magnitude of frequency change between notes and the speed of these changes to predict song performance. Using the trilled portion of song, we expect to find large variation in song performance for both song type within a species, and between subspecies. Further, we predict that beak shape and song performance are correlated. Taken together, our results may indicate that beak shape, which is presumably a naturally selected trait that varies with diet, can influence song, which is a sexually selected signal.

P1.32 CAUDLE, LD*; MAIA, A; Eastern Illinois Univ.; *lindsey.caudle.chs@gmail.com*

Murky Waters: Effects of Turbidity on the Vision and Behavior of Longear Sunfish

Fish are known to use vision in many essential behaviors, including foraging, intraspecific communication and predator avoidance. Turbidity is one of the environmental factors affecting vision quality. We examined the behavior of interacting conspecific fish in varying levels of turbidity to determine how this environmental variable affects vision and behavior. Experiments were designed to observe how longear sunfish,*Lepomis megalotis*, reacted to visual cues -in this case a conspecific fish in a glass jar - under varying levels of turbidity. Our hypothesis is that sunfish will display territorial behavior when introduced to another fish of the same species, so long as it sees the fish. These behaviors are hypothesized to decrease as turbidity increases and thus, visibility decreases. A single sunfish was placed in a tank and allowed to acclimate for 30 minutes. Then, either an empty glass jar (negative control) or a jar containing a conspecific fish was added to the tank. Behaviors were observed for 30 minutes in varying levels of turbidity. Turbidity was controlled using a circulation pump to stir sediment in the bottom of the tank and measured using a Secchi disk. Territorial behaviors such as bumping or head-butting the jar and circling near the other fish were observed when the fish interacted with a conspecific in non-turbid trials. Fish in turbidity with a conspecific behaved more similarly to fish in negative control trials (empty jar) than to fish in clear water with the presence of a conspecific. This suggests that fish do not react to conspecifics when exposed to turbidity, most likely because their vision is impaired. Our findings suggest that visual impairment caused by turbidity alters the behavioral interactions between conspecifics, potentially affecting territorial distribution and mating habits.

23.7 CAVE, EJ*; KAJIURA, SM; Florida Atlantic University; *ecave@fau.edu*

Effect of Deepwater Horizon Crude Oil on Olfactory Responses in the Atlantic Stingray, Dasyatis sabina

Crude oil causes both lethal, and a variety of sublethal effects on marine organisms, but the impact upon sensory function remains largely unexplored. The elasmobranch fishes often represent the upper trophic level predators in the marine ecosystem and thus rely upon the effective functioning of their sensory systems. Olfaction is used in prey, mate, and predator detection, and the olfactory epithelium is in direct contact with the seawater where it is exposed to environmental pollutants. The objective of this study was to test the effect of crude oil upon the olfactory sensitivity of a benthic marine predator, the Atlantic stingray, *Dasyatis sabina*. Stingrays were exposed to a 10% dilution crude oil solution, which replicates the concentration measured empirically in coastal areas following the Deepwater Horizon oil spill. An electro-olfactogram (EOG) technique was employed to quantify the response of the stingrays to five amino acids with different characteristics: Cysteine-polar, Alanine-non-polar, Phenylalanine-aromatic, Glutamic acid-acidic, and Arginine-basic. The magnitude of the EOG response for all amino acids was significantly depressed by 26% (Glutamic Acid) to 157% (Cysteine) in oil-exposed animals compared to control animals held in pristine water. Additionally, the EOG response onset was significantly slower, and the clearing time was protracted in oil-exposed individuals compared to control animals. These effects could ultimately lead to the stingray failing to detect prey, mates, or predators, which would detrimentally impact fitness. Further study is required to elucidate the mechanism responsible for the observed effects. This study is the first to quantify the effects of crude oil on the olfactory system of a marine predator.

82.5 CAVES, EM*; CHEN, CC; JOHNSEN, S; Duke University; *eleanor.caves@gmail.com*

Coarse vision isn't useless vision: cleaner shrimp use monochromatic, low-resolution vision to detect client fish

Cleaner shrimp live on coral reefs and provide cleaning services to client fish by removing and eating ectoparasites. However, how they detect and recognize clients and decide to engage in cleaning behavior is unknown. Our previous research has shown that cleaner shrimp vision is likely monochromatic and that their spatial acuity is too coarse to resolve the color patterns of their reef fish clients. Here, we ask whether or not cleaner shrimp will solicit and engage in cleaning behavior based only on cues or signals perceived using their low-resolution visual system. First, we recorded footage in nature of cleaner shrimp in the genera *Ancylomenes* and *Lysmata* to create an ethogram of the behaviors they exhibit in the presence of clients. In the lab, we then exposed shrimp to synthetic "client fish" stimuli (solid black or white rectangles) displayed on a screen, and demonstrated that these shrimp respond using the same behaviors to both real clients in nature and synthetic client stimuli that are purely visual. Lastly, we determined which aspects of a visual stimulus elicit cleaning behavior from shrimp by manipulating our visual stimuli to have different shapes (rectangles, circles, triangles), colors (black or white), orientations (horizontal or vertical), and motions (constant motion, or entering the screen and then stopping). In nature, the decision of a shrimp to provide cleaning services is likely based on a combination of tactile, chemical, and visual cues. Here, however, we show that, despite having vision that is both color blind and coarse, cleaner shrimp do use their visual system to discriminate between different stimuli and to facilitate the decision to engage in cleaning behavior.

110.5 CEJA, AY*; LAM, E; ABEGAZ, MF; SOUTHER, JL; YOU MAK, K; GUNDERSON, A; STILLMAN, JH; TSUKIMURA, B; San Francisco State Univ., Barnard College of Columbia Univ., Fresno State Univ.; *aceja1@mail.sfsu.edu*

Ecologically modeling the distribution of an intertidal crab concerning global change

Rising temperatures resulting from anthropogenically induced climate change have caused population distribution shifts over latitudes and altitudes. These range shifts often result in interspecific competition. *Petrolisthes cinctipes*, a porcelain crab dwelling in congregations under rocks in the mid-upper rocky intertidal zone, overlaps in range with *Petrolisthes manimaculis*, a competing congener species inhabiting the mid-lower intertidal zone. We implement an integrative ecological approach in which interspecific competition is addressed in efforts to predict the distribution of the model organism, *P. cinctipes*, under future climatic scenarios. This agent-based model applies predicted temperature profiles in conjunction with observed environmental (habitat temperature), physiological (Arrhenius breakpoint temperature), and behavioral (escape temperature and competition strength) data gathered from a *P. cinctipes* population at Fort Ross, CA. Rising temperatures correlate with a downward shift of the population to cooler microhabitats, leading to greater densities and increased interspecific competition. Modeling the heterogeneous thermal landscape of the intertidal zone resulting from elevational differences, tidal waves, and fluctuating solar radiation allows for extrapolation in predicting larger spatial scale distribution patterns. In predicting patterns of a highly variable environment, this model is applicable to similar multivariate systems with altitudinally distributed populations responding to biotic and abiotic factors.

50.8 CESPEDES, AM*; LAILVAUX, SP ; Univ. of New Orleans; *anniecespedes@gmail.com*
Long legs, big heads: Sex-specific multivariate morphology-> performance relationships in Anolis carolinensis
Animals are required to execute various ecological tasks during their lifetimes. These tasks often require different whole-organism performance abilities, and thus morphology has been shaped by selection to enable not just one kind of performance trait, but several. However, specialization for one type of performance may come at the detriment of other, necessary functions (e.g., stamina versus speed), resulting in functional trade-offs among performance traits. Furthermore, males and females may experience different performance demands, resulting in sexual conflict over performance expression that can either constrain performance evolution or drive sexual dimorphism in both size and shape. We tested for trade-offs among a suite of whole-organism performance traits (biting, clinging, climbing, jumping, sprinting, exertion and endurance) in the green anole lizard *Anolis carolinensis* by measuring relationships both among performance traits, and between morphology and performance while preserving the multivariate context in which these traits exist. We also tested for sex-specific differences in the morphology-> performance gradient. By controlling for sources of variation that can mask individual trade-offs, we both expose the morphological underpinnings of the multivariate performance phenotype and demonstrate the existence of sex-specific functional trade-offs in this species.

P1.57 CHAIYASARIKUL, A.*; WARKENTIN, K.M.; Boston University; *alinac@bu.edu*
Escape Hatching of Red-Eyed Treefrogs in Wasp Attacks: How Development Changes Survival
Red-eyed treefrogs (*Agalychnis callidryas*) lay egg clutches on vegetation over Neotropical ponds, and tadpoles fall into the water upon hatching. Embryos are subject to heavy predation; in prior work, half the clutches monitored at a pond were attacked by social wasps (*Polybia rejecta*). Some embryos escape from attacks by hatching rapidly and prematurely, but at a cost of higher predation risk as tadpoles. Predator-induced hatching begins at age 4 days and is initially highly variable among clutches. With development, escape success improves and becomes more consistent, so most 5-d embryos survive attacks. To understand how developmental changes in embryo behavior, decisions, and escape performance contribute to their changing fates in attacks, we recorded macro-video of wasp interactions with 4 and 5-d embryos near a pond in Panama. Escape success varied from 0-100% among studied clutches, improving strongly with development. From our video analysis, we identified two major changes that contribute to the developmental increase in survival. First, development increased the chance that an embryo would hatched pre-emptively, in response to wasp activity on its clutch, rather than waiting for a direct attack that ruptured its egg. Almost all of these hatchlings survived. Second, development improved embryos' chances of escaping from egg capsules that were directly attacked and ruptured by a wasp. Such escapes occurred during both intense struggles and periods when the wasp stepped away from the ruptured egg. Thus, it appears that changes in both embryo decisions during attacks on their clutch and escape-hatching performance under direct attack contribute to ontogenetic changes in embryo fates.

P1.29 CHAKKA, K*; BAO, Y; MUSCEDERE, ML; Hendrix College, Conway, AR; *ChakkaKK@hendrix.edu*
Behavioral Acceleration After Injuries in the Ant Pheidole dentata is Accompanied by Changes in Brain Amine Levels
Ants are one of the few organisms that exhibit efficient social behavior involving a division of labor among nestmates. *Pheidole dentata* worker task performance patterns are variable. As in most ants, young workers are usually found in the nest caring for brood and sharing food, transitioning to riskier outside-nest tasks like foraging and defending the nest when they are older and physiologically mature. This flexible process of behavioral maturation is known to be affected by environmental factors like colony demography and task demand, as well as innate physiological mechanisms such as maturation of neuromodulatory biogenic amine systems in the brain. It has been suggested that injured ants could maximize colony fitness by assisting with dangerous tasks earlier than normal, similar to the behavior of older, uninjured ants. The physiological basis of this phenomenon has never been investigated. By injuring some ants by amputating an antenna or hind leg and comparing them to control ants of the same age, we observed differences in aggression level and propensity to leave the nest between each group. After being lesioned on the day of eclosion, ants were more likely to be outside of the nest 13, 14, and 15 days later when compared with same-aged control ants. Injured ants were also more aggressive in encounters with dead non-nestmate workers (competitors) and live fruit flies (prey items). Lastly, injured workers had increased brain biogenic amine levels. Since aminergic signalling has been shown to affect behavioral maturation in social insects, these changes could be causally related to the observed behavioral differences. Our study supports the growing consensus that physiological and environmental influences interact to influence worker task performance in insect societies.

P1.168 CHAN, K.Y.K*; NG, T.P.T; NGO, J.; WILLIAMS, G.A. ; Hong Kong Univ. of Sci. and Tech. , The Univ. of Hong Kong; *karenchan@ust.hk*
Taking the heat: High thermal tolerance of larval and adult mangrove snails
Climate change is threatening global biodiversity. An organisms' sensitivity to climate change depends on their thermal safety margins (i.e., how close they live to their thermal limits) throughout their life histories. Such safety margins are thought to be smaller in tropical terrestrial ectotherms compared to their temperate counterparts due to both local acclimation and adaptation to a relatively stable thermal environment. However, to date, there is little information on the thermal safety margins of marine ectotherms. Importantly, these ectotherms have multi-phasic life histories and depend on a planktonic stage for dispersal. This crucial, but largely unprotected stage is considered to be especially vulnerable to environmental stressors; and is often viewed as the limiting stage for the distribution and abundance of these species. We investigated thermal safety margins of larval and adult stages of two species of mangrove snails, *Littoraria ardouiniana* and *L. melanostoma*, Surprisingly, both larvae and adult snails had high and comparable upper thermal limits, lethal temperatures of larvae and Arrhenius Breakpoint Temperature of adults exceeded 43°C. The larval thermal limit was well-above the observed sea surface temperature (Tmax: 33°C), whereas present-day ambient temperatures in the tree canopy could exceed the adult limits (Tmax 46°C). The larval stages, therefore, have a much greater thermal safety margin as compared to the adults, which may reflect adaptation of these marine ectotherms to the most stressful phase of their life cycle.

3.2 CHAN, K.Y.K.*; NGO, J. ; Hong Kong Univ. of Sci. and Tech. ; *karenchan@ust.hk*

Is it mom's or dad's fault? Effects of ocean acidification on gametes and fertilization success of the tropical sea urchin Heliocidaris crassispina

Ocean acidification (OA), the reduction of ocean pH due to dissolution of anthropogenic carbon dioxide, has been shown to negatively affect fertilization of various marine invertebrates. Thus far, most studies have focused on how reduction in pH affects sperm motility without considering the potential impacts on eggs. Sea urchin eggs have a characteristic layer of jelly coat, which is suggested to increase target size for sperm and for species recognition. Here, we exposed the gametes of a tropical sea urchin, *Heliocidaris crassispina*, to a broad range of pH (pH 6.5 - 8) and quantified jelly coat thickness, sperm motility, and fertilization success over time. Consistent with previous studies, sperm swimming velocity decreased with pH reduction. Thickness of jelly coat also changed with pH: eggs that were spawned into low pH had significantly thinner jelly coats. In the extreme pH treatment (6.5) the jelly coats were on average ~20% thinner than those in the control (pH 8). Despite the observed reduction in sperm motility and jelly coat thickness, fertilization success remained high (>80%) even at the lowest pH treatment. Our results suggest that even gametes were negatively impacted by OA, fertilization could still occur provided there was sufficient sperm density. And yet, the fertilized embryos exposed to pH 7.4 or below failed to divide beyond the two-cell stage, suggesting sensitivity to acidification in later developmental stages could be more detrimental to urchin populations than fertilization.

P3.59 CHAN, J*; HARTLEY, M; BAKER, A; PLACHETZKI, D; Univ. of New Hampshire; *mav327@wildcats.unh.edu*

A Role for Adenylate Cyclase in Cnidarian Phototransduction

Cnidarians such as the freshwater polyp Hydra magnipapillata display a surprisingly complex sensory repertoire capable of responding to light, chemical, and mechanical stimuli. The photo response in hydra is driven largely by an opsin-mediated phototransduction cascade that utilizes cyclic nucleotide gated ion channels, however, the intermediary enzymes involved in cnidarian phototransduction have not been directly examined. Previous work demonstrated an increase in cytosolic cAMP in heterologous gene expression studies of a jellyfish opsin. In eukaryotic cells, cAMP is generated by adenylate cyclase (AC) and a cross-reactive antibody against AC stained the photoreceptor layer of a cubozoan rhopalia. Here we directly test the possibility that AC acts in phototransduction in the hydra. We report an exhaustive phylogeny of metazoan AC genes and show that cnidarian genomes possess orthologs of metazoan AC9. Next we show riboprobes against hydra AC9 co-localize with opsin in a range of hydra sensory neurons. Finally, we use a simple photo response experiment, where dark-adapted hydra are presented with light of differencing wavelengths and assayed for contraction, in the presence and absence of drugs that effect AC activity. Our results suggest that AC activity is likely involved in the hydra photo response and may be a general feature of cnidarian phototransduction. We discuss these results in light of current hypotheses on the origin and diversification of animal phototransduction cascades.

136.5 CHANDLER, S*; SPONBERG, S; Georgia Institute of Technology; *steven.chandler@gatech.edu*

Flight Control Compensation to Changing Body Mass in Feeding Hawkmoths

Motor control of animals has been shown to be quite robust to mechanical and environmental variation. In studying motor control, tracking behaviors have revealed important insights into sensory processing and motor performance due to their well defined tasks. However, much of the work studying these behaviors has focused on manipulating the sensory side of the animal's sensorimotor feedback loop and less on examining the robustness of animals to behaviorally relevant changes in their mechanics. The hawkmoth, *Manduca sexta*, forages nectar from flowers while hovering and will feed enough to increase their body mass by more than 70%. Using a robotic flower following a prescribed 2D sum-of-sines trajectory, we measured the dynamic response of continually feeding, freely flying moths for a 60 second period leading to a mean increase in mass of 26% (5% SD). We used a control theoretic feedback model assuming simple inertial mechanics to compare the observed change in response to a predicted, uncompensated response given the measured increase in body mass. If the moths did not compensate for increasing mass, the phase difference between the flower and moths would increase. However, the observed response shows a decrease in the phase lag of the moths as they feed. This suggests compensatory neural control that helps maintain the neuromechanical performance of the system. A possible method of compensation is the moth phase shifting its response forward while simultaneously reducing the gain. This model and method supports the idea of a high pass sensory controller leading to an overall low pass locomotor response as has been found in other locomoting animals. Furthermore, the method suggests how the moth may be adjusting to provide robust maneuverability in the face of an ecologically relevant change in inertia.

P1.259 CHANG, E*; LENTINK, D; Stanford University; *echang7@stanford.edu*

How Pigeon-inspired Morphed Wings Affect Glide Performance in Turbulence

While micro air vehicles have difficulty flying in highly turbulent conditions such as dense urban landscapes, many birds can navigate through these environments with ease. Avian wing morphing leads to enhanced flight performance, so we further hypothesize that certain morphed wing shapes are more stable in turbulence than others. To study this in real-world turbulent conditions, we use a gliding aerial robot platform inspired by the pigeon (*Columba livia*) to test the effects of turbulence on different morphed wing configurations. The platform is capable of fully autonomous flight while logging accelerometer, gyroscope, GPS, and compass data. To test morphed wing configurations, we swap in and out different interchangeable wing modules. We derived these wing shapes from in vivo measurements of gliding pigeons at different glide angles and speeds. By understanding the performance of differently morphed wings, we can apply control strategies to morphing wing robots for flight in complex urban environments.

P3.200 CHANG, U*; ALLEN, B; RANKIN, CJ; Univ. of California, Davis, Duke Univ., Univ. of the Witwatersrand; *ukyoung.chang@gmail.com*

Mantid hind limb morphology is related to vegetation complexity in South African savannas

In a savanna ecosystem, fire and herbivory are the two major disturbances that engineer structural complexity in vegetation. Vegetation complexity, in turn, affects insect diversity and morphology in some systems. Previous studies examining the effects of vegetation structure on insects have focused mainly on plant-feeders, whereas predatory insects like mantids have received little attention. In this study, we examined mantid diversity and morphometrics in three structurally distinctive, South African savanna habitats shaped by fire and herbivory: long bunchgrass, grazing lawns, and recently burned plots. Mantids were categorized into morphospecies based on body length and hind femur length - a trait related to maneuverability, which is important for both prey capture and predator escape. A greater number of morphospecies were identified in bunchgrass, the most complex vegetation. The largest individual mantid was also found in bunchgrass, although there was no significant difference in average body length across vegetation types. Mantids found in bunchgrass had significantly shorter hind femurs than those found in the other habitats - an effect that may be driven by limited maneuvering space, reduced predation risk, and the need to negotiate small spaces while searching for prey. Conversely, mantids in less complex vegetation rely more on mobility to escape from predators and capture prey, and most morphospecies in grazing lawns and recently burnt plots displayed proportionately longer hind limbs. The one exception to this pattern was *Pyrgomantis rhodesica*, which had shorter hind limbs but exceptionally long forelimbs; as a known ambush predator, this species likely relies on crypsis and its long reach to capture prey, even in relatively open habitats.

30.1 CHANG, J*; ROY, K; BAUM, JK; COWMAN, PF; FRIEDMAN, M; SALLAN, LC; CLARKE, JT; ALFARO, ME; Univ. of California, Los Angeles, Univ. of California, San Diego, Univ. of Victoria, James Cook Univ., Univ. of Oxford, Univ. of Pennsylvania; *jonathan.chang@ucla.edu*

Size-selective harvesting and the macroevolutionary implications of an "anthropogenic filter" in ray-finned fishes

Size-selective harvesting of fishes is known to cause large changes in exploited species' phenotypes, yet other possible macroevolutionary implications of this pervasive harvest remain unexplored. One proposed process that may be occurring is an "anthropogenic filter", where human consumers preferentially exploit fishes with specific phenotypes, ecologies, or habitats. We test this hypothesis by quantifying the phylogenetic distribution of fished species on the largest fish phylogeny assembled with over 11,000 tips. We show that fished species are more closely related to each other than expected. Additionally, we find that although species are exploited across a range of body sizes, exploited lineages still tend to be larger than unexploited lineages. A large-scale analysis of habitat types also reveals that exploited species tend to occur in reef habitats and in coastal and shallow water systems. These findings are consistent with the "anthropogenic filter" hypothesis, suggesting that human exploitation of fishes could lead to unpredictable macroevolutionary impacts, as well as altered ecosystem function due to changes in the community structure of productive reef and coastal environments. Our results have broad implications for marine conservation efforts to mitigate these potentially negative effects of anthropogenic exploitation.

82.2 CHAPPELL, DR*; SPEISER, DI; Univ. of South Carolina, Columbia; *danielrc@email.sc.edu*

Certain chitons have hundreds of image-forming eyes, but what are they seeing?

Sensory biology research has mostly focused on paired cephalic sensors that are connected to a relatively complex brain; however, some organisms have dispersed sensory systems with relatively simple nervous systems. How do simple nervous systems process large amounts of information from a multitude of distributed sensors? Certain species of chitons (Mollusca: Polyplacophora) have hundreds of image-forming eyes embedded in their 8 dorsal valves. Chitons are classically thought to have simple ladder-like nervous systems, so the evolution of a multitude of information-rich sensors seems to present a computational challenge to these animals. Learning how the optic nerves connect with the rest of the nervous system in chitons may give us insight into how chitons are processing the visual information collected by their eyes. To investigate this, the optic nerves from the eyes of *Acanthopleura granulata* were traced centrally using pressure microinjection of fluorescent lipophilic dyes. The optic nerves from eyes within the same region on a valve were found to coalesce after leaving the margin of the valve. They then traveled across the pallial groove where they terminated along the lateral nerve cord in proximity to where the eyes were located in the valves. Based on these results, we propose a model in which chitons process visual information locally from multiple eyes within certain regions of each valve. This is consistent with previous behavioral experiments that suggested that chitons process mechanosensory data locally.

9.3 CHARBONNEAU, D*; DORNHAUS, A; University of Arizona; *charbonneau.daniel@gmail.com*

Who Are the 'Lazy' Ants? Inter-worker Variation Gives Insight into Potential Functions of Inactivity

Social insect colonies are commonly thought of as highly organized and efficient complex systems. And yet, social insects are also known to have high levels of worker inactivity. Not only is inactivity common, but a subset of workers effectively 'specialize' on inactivity, suggesting that inactivity does not result from constraints shared by all workers, such as a physiological need for rest. Some studies have tested potential links between inactivity and worker reproduction, worker age/ontogeny, and food storage, but very little is still known about the adaptive functions or costs associated with this behavior. Here we concurrently test five separate but non-exclusive hypotheses for worker inactivity using behavioral, physiological, and morphological differences between inactive workers and their nestmates. Our data show that inactive workers have larger bodies, greater corpulence, limited task repertoires, spatial fidelity zones, and interactions with nestmates, suggesting that inactivity may be linked to slow pace-of-life, age polytheism, and acting as food stores. Simultaneous functions of inactivity may explain the difficulty in finding a simple answer to this complex question.

P3.208 CHARIFSON, DM; Stony Brook University; *david.charifson@stonybrook.edu*

Phenotypic Plasticity in Gastropod Shell Microstructure: Effect of Predator Cues and Reduced Growth Rates

Many gastropod species have inducible defenses when exposed to chemical cues from predators. This plasticity is known to manifest in traits like shell growth, thickness, and shape. However, only a few studies have examined shell microstructural responses to predators and these only quantified microstructure at or near the aperture, ignoring remodeling or thickening of the body and apical whorls. The various types of molluscan shell microstructures are known to have different biomechanical properties and could alter the role of the shell as a defense against predators. I experimentally tested if there are inducible microstructural differences in *Littorina littorea* in response to the invasive predatory crab *Hemigrapsus sanguineus* and in response to a lower growth rate. Snails from three Long Island Sound populations were used in the experiment to detect differences in response to the predator and reduced growth, as well as overall differences in thickness of microstructural layers among these populations. *L. littorea* shells are composed of two types of microstructure: 1) an outer irregular prismatic layer composed of calcite, and 2) an inner crossed lamellar microstructure made of aragonite. Microstructure was quantified using sections through the aperture and through the columella, allowing me to determine microstructural plasticity throughout the entire shell. Preliminary results suggest differences in thickness of layers among populations with one population with a thinner crossed lamellar layer, especially near the apex.

P2.118 CHEESMAN, SC*; MOURNIGHAN, DT; CARRUTH, LL; Georgia State University; *scheesman2@student.gsu.edu*

Singing in different social contexts alters song rate in male zebra finches housed with female partners

Female zebra finches (*Taeniopygia guttata*) choose mates based on a number of factors that indicate male quality, including song rate, song complexity (Clayton and Prove, 1989; Collins, 1999), and redness of the beak (Simons and Verhulst, 2011). With regards to selecting mates based on song, females typically prefer males that spend more time singing which correlates with other fitness benefits such as territory quality, food availability and increased parental care (Alatalo, et al., 1990; Greig-Smith, 1982). Females also prefer males who sing more frequently and at a faster rate (Houtman, 1992). During an ongoing study to identify the neural mechanisms of how captive female partner preference is altered by acute stress we asked if song rate of males classified as "low quality" or "high quality" (using the parameters described above) is altered by the social context in which song is produced, including parenting and non-directed social singing with non-partner aviary mates. Male song was recorded in the presence of a partner and separately in the presence of its both its partner and offspring and general aviary cage mates (with comparisons made for variations in offspring age, sex, and clutch size). Songs were recorded for 9 males for 5 days (6 hours/day) and the differences in song rate between the different social contexts were determined. Our results show that social context alone is sufficient to alter song rate, but other factors influencing male quality are important. Male zebra finches classified as "low quality" and "high quality" can modify singing strategies when social context changes.

31.4 CHEJANOVSKI, Z/A*; KOLBE, J/J; University of Rhode Island; *zchejanovski@gmail.com*

Abiotic and Biotic Determinants of Lizard Body Size Across an Urbanized Landscape.

Understanding the effects of human-induced environmental change on animal populations is currently the focus of many ecological and evolutionary studies. For example, urbanization is associated with altered abiotic and biotic conditions in cities around the world and these changes can influence key morphological traits. For the brown anole (*Anolis sagrei*), previous work in southeast Florida has shown that individuals from urban environments are consistently larger (i.e. snout-vent length) and in better body condition (i.e. mass/length) compared to conspecifics from natural habitats. Such variation in body size can have important consequences for the competitive ability, diet, and habitat use of these lizards. However, determining the factors responsible for body size variation between urban and natural populations, as well as among urban populations remains unresolved. To address this, we compared the body size of brown anoles from populations across a gradient of urbanization including natural forest environments. From each of these populations, we quantified factors that may contribute to body size variation such as body temperature, availability of solar radiation, food availability and diversity, conspecific density, and predator abundance. Our results confirm that urban lizards are larger and in better condition than their natural forest conspecifics, but the factors contributing to body size variation across these environments are complex and may include predator and conspecific abundances. Urban areas are predicted to spread and intensify over the next 50 years; therefore, it is critical to identify the features of urban areas with the greatest impact on animal communities so as to inform managers and mitigate future declines in biodiversity.

P2.111 CHEN, HY*; KANG, BJ; WILDER, MN; JIRCAS; *chenh52@affrc.go.jp*

The involvement of red pigment-concentrating hormone (RPCH) in female reproduction in whiteleg shrimp (Litopenaeus vannamei)

Reproduction in female crustaceans is controlled via the coordination of various hormones. In this study, the effects of a red-pigment concentrating hormone (Liv-RPCH) previously cloned from eyestalks, on ovarian growth were assessed. Artificially-synthesized Liv-RPCH was employed in both in vitro and in vivo assays; various measurements were conducted in order to evaluate the influence of Liv-RPCH on different physiological parameters. In a 24-hr in vitro incubation, RPCH alone did not stimulate oocyte growth; only ovaries co-incubated with either brain or thoracic ganglia with the addition of Liv-RPCH showed a significant increase in mean oocyte area. Regarding in vivo experimentation, measurements including that for ovarian Vg mRNA levels, hemolymph vitellogenin concentrations, and mean oocyte area were performed 25 days after the injection of Liv-RPCH. Results showed that Vg mRNA expression in ovaries, circulatory vitellogenin concentrations, as well as mean oocyte area were all significantly increased in animals receiving Liv-RPCH. Evidence from other lines had suggested that serotonin (5-HT) may stimulate ovarian growth in crustaceans. To further elucidate whether Liv-RPCH is involved in 5-HT induced-ovarian maturation, Liv-RPCH expression was examined in eyestalks, brain, thoracic ganglia and ovaries by means of quantitative real-time PCR at 0, 3 and 6 hr after 5-HT injection. The mRNA levels of Liv-RPCH in eyestalks, brain, and thoracic ganglia showed no significant changes within 6 hr after injection. However, the expression of Liv-RPCH in the ovaries was upregulated after 3 and 6 hr of 5-HT injection, suggesting that Liv-RPCH is involved directly or indirectly in 5-HT-stimulated ovarian growth. Overall, the above results strongly suggest that Liv-RPCH participates in ovarian growth in *L. vannamei* .

P2.192 CHESKO, S*; WILCOXEN, TE; SEITZ, J; NUZZO, J; Millikin University, Illinois Raptor Center, Illinois Raptor Center; *schesko@millikin.edu*

Lead Poisoning in Central Illinois Birds of Prey

Some studies of raptors across the United States have revealed lead poisoning in these birds, linked to human activities. Lead has negative neurological and hematological impacts on birds. Although several steps have been taken toward solving this issue, ingestion of lead from the food raptors consume is potentially a much greater conservation issue than previously indicated. We collected blood samples from raptors admitted to the Illinois Raptor Center in Decatur, Illinois for rehabilitation from March 2014 to December 2016 and determined lead content with an ESA LeadCare II lead analyzer. We tested if lead toxicity appears at a frequency in any species at a rate that differs from random. We also used spatial autocorrelation analyses to determine if birds that were positive for lead were associated with specific hunting regions and matched the results of the spatial autocorrelation analyses with public hunting data found through the Illinois Department of Natural Resources. After finding that non-scavenging species, such as Cooper's Hawks, frequently showed high levels of lead, we also tested common prey species in the area. Lead toxicity does appear among species at a rate that differs from random, with scavengers representing the highest proportion of high lead individuals. We also found that there was no significant association between Hunting Region 3 and 4, despite substantial differences in hunting activity. Further, we found evidence that lead is prevalent in the living prey base of many of these species, particularly in urban pigeons. Overall, our work will help better understand the sources of lead in multiple species of raptors, including these non-scavenger species.

P3.210 CHEU, AY*; BERGMANN, PJ; Clark University; *acheu@clarku.edu*

Increasing Complexity of Form-Function Relationships When Considering Multiple Modes of Locomotion

Natural selection acts upon an organism's ability to perform well at ecologically-relevant tasks. These tasks are affected by the organism's underlying phenotypic traits. However, one phenotypic trait does not necessarily impact the performance of a single task. Instead, one trait may affect multiple tasks or many traits may redundantly affect one task. Many-to-many mapping of form-to-function is a concept that considers how multiple phenotypic traits affect multiple performance measures within the same system. However, in previous form and function relationship work, only two measures of performance have been considered at a time. By considering greater numbers of performance measures, we are able to examine how trade-offs and facilitations can affect a given phenotypic trait simultaneously. Here, we look at five different modes of locomotion: bipedal sprinting, jumping, climbing, running on water, and swimming in brown basilisk lizards (*Basiliscus vittatus*) to examine the relationships between variation in phenotypic traits and variation in the performance of these different types of locomotion. *Basiliscus vittatus* is a highly dynamic performer that performs well at all of these modes of locomotion in nature, given it is terrestrial, arboreal, and aquatic. By relating phenotype to performance via the statistical model, the F-matrix, we are able to quantify these complex relationships. Our findings show that it is important to consider a wide array of tasks to comprehensively understand how trade-offs and facilitations impact the functional architecture of an organism. The F-matrix approach also allows us to predict which traits are most readily evolvable, given the system's functional constraints.

S4.2 CHEVIRON, ZA*; STAGER, M; SWANSON, DL; University of Montana, University of South Dakota; *zac.cheviron@mso.umt.edu*

Comparative transcriptomics of seasonal phenotypic flexibility in three species of North American resident songbirds.

Phenotypic flexibility allows organisms to reversibly alter their phenotypes to match the demands of temporally fluctuating selective pressures in seasonal environments. While the adaptive value of properly matching phenotypes to prevailing environmental conditions is clear, the physiological and regulatory mechanisms that underlie seasonal changes in phenotype are not. Because phenotypic flexibility is mediated, at least in part, by changes in gene regulation, we conducted a series of comparative studies to identify transcriptomic changes associated with seasonal shifts in thermogenic performance in three species of resident North American songbirds. In this talk, I will synthesize the results of these studies, which include surveys of seasonal transcriptomic changes in free-ranging, wild birds and acclimation experiments on captive individuals. These studies point to three main insights about the regulatory changes that contribute to seasonal phenotypic flexibility. First, co-expression network analyses revealed transcriptional modules of co-regulated genes that were highly conserved across species. Second, while only a subset of the transcriptional modules were associated with higher-level physiological traits and showed seasonal changes in expression, these associations were also conserved across species. Finally, acclimation studies of captive Dark-eyed Juncos revealed that most of these seasonally flexible and phenotype-associated modules respond to cold exposure, rather than to changes in photoperiod. Together, these studies provide the first comprehensive overview of potential common regulatory mechanisms underlying seasonally flexible phenotypes in birds.

78.3 CHICOINE, S.J.*; LEONARD, J.B.K.; Northern Michigan University; *schicoin@nmu.edu*

Effects of Winter and Summer Thermal Variability Regimes on Growth and Metabolism in Brook Trout (Salvelinus fontinalis)

Brook trout (*Salvelinus fontinalis*) is a cold water species with a narrow range of thermal tolerance. Climate change projections suggest that in addition to increases in average temperatures worldwide, we should expect greater temperature variability. We are investigating growth and metabolic responses of brook trout to daily thermal variation. We reared groups of brook trout under constant temperature to serve as a control, a 4°C daily range as a low variability treatment similar to current conditions, and an 8°C daily range as a high variability treatment mimicking climate change predictions centered on a 6°C for winter or 12°C for summer. Over the two-month treatment exposures, we measured the mass and length of fish from each group to assess growth rates, collected plasma to measure cortisol, T3, and T4, and white muscle for citrate synthase activity. At the end of each treatment exposure series, a subsample of fish from each group was exposed to swimming respirometry to assess active and inactive metabolic rate and metabolic scope. Preliminary results suggest that there was no effect of variability in the daily thermal profile under our winter temperature regimes.

41.1 CHIN, DD*; LENTINK, D; Stanford University;
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How Birds Direct Impulse to Minimize the Energetic Cost of Foraging Flight

Foraging arboreal birds frequently hop and fly between branches by extending long-jumps with a few wingbeats. Their legs transfer impulse to the branch during takeoff and landing, and their wings transfer impulse to the air to support their bodyweight during flight. To determine the mechanical energy tradeoffs of this bimodal locomotion, we studied how Pacific parrotlets, arboreal generalist birds, transfer impulse during voluntary perch-to-perch flights for a seed reward. Five foraging flight variations were tested inside a novel aerodynamic force platform by varying the inclination and distance between instrumented perches. This setup enables direct, in vivo measurements of both leg and wing forces, which we combined with high-speed kinematics to develop a new bimodal long-jump and flight model. Using this model, we discovered that parrotlets direct their leg impulse to minimize the mechanical energy needed for each flight. The bimodal locomotion model may also lend insight into the evolution of foraging flight, as it shows how even a single proto-wingbeat would have significantly lengthened the long-jump of foraging arboreal dinosaurs. By directing jumps and flapping their wings, both extant and ancestral birds could thus improve foraging effectiveness. Similarly, bimodal robots could also employ these locomotion strategies to traverse cluttered environments more effectively.

36.6 CHIODIN, M; KAYAL, E; OHDERA, A; MEDINA, M; PLACHETSKI, DC; COLLINS, AG; RYAN, JF*; Whitney Laboratory for Marine Bioscience, Smithsonian Institution National Museum of Natural History, Penn State University, Penn State University, University of New Hamphsire;
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You gain some, you lose some: Hox genes in the early history of Cnidaria and Bilateria

Hox genes are homeobox transcription factors essential for patterning the primary body axes of cnidarian and bilaterian animals. Genomic evidence from *Nematostella vectensis* (Anthozoa), *Acropora digitifera* (Anthozoa), and *Hydra magnipapillata* (Hydrozoa) has provided initial insights into the Hox complement of the cnidarian-bilaterian ancestor (CBA), but the exact orthology of many of the cnidarian Hox genes remains a mystery. Consequently, very little is understood about the evolution of these genes within Cnidaria or in the stem lineage of Bilateria. To add more resolution to these questions, we have sequenced and assembled new genomes from all of the major cnidarian lineages that currently lack such resources (i.e., Octocorallia, Cerianthidae, Cubozoa, Staurozoa, and Scyphozoa) and analyzed the Hox content of these datasets along with available cnidarian transcriptomes. Our analyses suggest that the CBA possessed several Hox genes that are no longer present in bilaterians. In addition, we found Hox genes present in some cnidarian lineages that were apparently lost in anthozoans and the model hydrozoan *Hydra magnipapillata*, which may affect hypotheses regarding the origin of Posterior and Central Hox genes. Lastly, we document extensive loss of Hox and Hox-related genes in Medusozoa and Myxozoa. These new results document notable Hox gene losses in lineages marked by major shifts in body plan and life history strategies, and as such, have important implications for a better understanding of the early evolution of animals.

S7.8 CHIPMAN, A.D.; The Hebrew Univ.;
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The evolution of the gene regulatory networks that define arthropod body plans

Our understanding of the genetics of arthropod body plan development originally stems from work on *Drosophila melanogaster* from the late 1970s and onwards. In *Drosophila* there is a relatively detailed model for the network of gene interactions that proceeds in a sequential-hierarchical fashion to define the main features of the body plan. Over the years, we have a growing understanding of the networks involved in defining the body plan in an increasing number of arthropod species. It is now becoming possible to tease out the conserved aspects of these networks and to try to reconstruct their evolution. I will focus on two key nodes of these networks. The first is the blastoderm phase in which the main axes are determined and the broad morphological domains of the embryo are defined. The second is the growth zone network, through which posterior segments are added sequentially. The blastoderm network pre-dates the radiation of holometabolous insects and contains a core of conserved interactions. The growth zone network is much more ancient and is probably plesiomorphic to all arthropods. It has undergone a significant amount of systems drift, wherein many of the genes have changed. However it maintains a conserved underlying logic and function.

P2.232 CHIVERS, D.P.*; MCCORMICK, M.I.; ALLAN, B.J.; MITCHELL, M.D; FERRARI, M.C.O.; University of Sakatchewan, James Cook University; *doug.chivers@usask.ca*
At odds with the group: changes in lateralization and escape performance reveal conformity and conflict in fish schools

Many vertebrates are known to show behavioural lateralization, whereby they differentially use one side of their body or either of their bilateral organs or limbs. Behavioural lateralization manifests in a turning bias in fishes, with some individuals showing a left bias and others a right bias. Such biases could be the source of considerable conflict in fish schools given that there may be considerable social pressure to conform to the group to maintain effective group evasion. Here, we show that predation pressure is a major determinant of the degree of lateralization, both in a relative and absolute sense, in yellow-and-blueback fusiliers (Caesio teres), a schooling fish common on coral reefs. Wild caught fish showed a bias for right turning. When predation pressure was experimentally elevated or relaxed, the strength of lateralization changed. Higher predation pressure resulted in an increase in the strength of lateralization. Individuals that exhibited the same turning bias as the majority of individuals in their group had improved escape performance compared to individuals that were at odds with the group. Moreover, individuals that were right biased had improved escape performance, compared to left-biased ones. Plasticity in lateralization might be an important evolutionary consequence of the way gregarious species respond to predators due to the probable costs associated with this behaviour.

101.6 CHMURA, HE*; MEDDLE, SL; WINGFIELD, JC; HAHN, TP; Univ. of California, Davis, Univ. of Edinburgh; *hechmura@ucdavis.edu*

Comparing the Effects of a Social Cue on Reproductive Development in Seasonally Breeding Migrant and Resident Female Songbirds (Zonotrichia leucophrys)

Preparation for seasonal events such as breeding begins months in advance in response to diverse cues. The type of cue(s) that organisms respond to may depend upon their ability to predict future conditions. Theory predicts that reproductive preparation in resident bird species responds more to variation in local climate and social environment than that of migrants, which begin gonadal maturation far from breeding grounds. Consequently, residents may shift reproductive phenology with a changing climate more rapidly than migrants. While photoperiodic cue use across avian taxa has been studied heavily, less is known about non-photic (e.g. temperature or social) cue use. This experiment compared the response of migratory and resident white-crowned sparrows *(Zonotrichia leucophrys)* to a male song cue. Wild caught migratory *(Z.l. gambelii)* and resident *(Z. l. nuttalli)* juvenile females were held on a naturally changing wintering ground photoperiod and experimental birds were exposed to subspecies-appropriate male song recordings. Reproductive preparation was tracked using monthly laparotomies, bi-weekly blood samples, and morphology (brood patch) and molt scoring. After 83 days, terminal measurements (ovary mass, oviduct mass, follicular size) were made. Reproductive development was highly variable and resident birds had more advanced ovaries and oviducts than migrants. Effects of song treatment were small, but suggested that residents respond more to song than migrants as predicted. Effects on reproductive hormones and pre-nuptual molt are also reported. Results suggest that further study of mechanisms that permit or constrain flexibility in reproductive phenology in migrants and residents is promising.

S6.4 CHOLERIS, E*; KAVALIERS, M; University of Guelph, University of Western Ontario; *echoleri@uoguelph.ca*

Neurobiology of Mate Choice and Social Recognition in Rodents,

Mate choice is a complex and flexible process that is context specific, and affected by various social factors (e.g. own or others' health/pathogen status, mate choice of others - "mate-choice copying"). Mate choice involves the acquisition and cognitive processing of information about others (i.e. social recognition) as well as information originating from others (i.e. social learning), accompanied by the exploitation and application of that information in subsequent decision making. In rodents odors are particularly important determinants of social behavior and mate choice, providing information on species, sex, individual and class identity and kinship of the owner, as well as information on an individual's current reproductive, social, health and infection status. Odor-driven mate choice involves a very quick detection and recognition of potential partners and a similarly very quick neurohormonal mediation of the behavioral and physiological responses to them. These rapid responses involve a variety of neurobiological regulatory mechanisms associated with social recognition and social learning. These includes evolutionarily conserved neurotransmitters, opioid systems, sex steroid hormones (testosterone and, in particular, estrogens), nonapeptide systems (oxytocin, arginine-vasopressin) and their receptors. As these neuromodulatory systems and responses are dynamic and vary between individuals this allows for substantial environmental and social influences on the expression of the appetitive and consumatory components of mate choice. Supported by NSERC

P3.70 CHOU, A*; LIN, C; CRONIN, TW; University of Maryland, Baltimore County; *achou2@umbc.edu*

Comparative neuroanatomy of the crustacean central complex

In arthropods, the central complex (CX) is a collection of midline neuropils commonly implicated in sensory integration and pre-motor control. The organization of a species' CX often correlates with sensory complexity and/or motor "dexterity". For example, polarization e-vectors are topographically represented in the desert locust protocerebral bridge, which suggests that here the CX plays a role in processing polarized-light information. Furthermore, the CX of insects with elaborate motor repertoires, like the spiny Australian stick insect, is organized into distinct columns, whereas the CX of insects with reduced motor behaviors, such as earwigs, lack such organization. Mantis shrimps, also known as stomatopod crustaceans, are marine arthropods famed for their unique sensory attributes and dynamic predatory behavior. However, little work has been done to characterize their central complex. Here, we present CX neuroarchitecture of two species of stomatopod crustaceans, *Neogonadactylus oerstedii* and *Squilla empusa*, and the decapod crustacean *Procambarus clarkii*—three aquatic arthropods with distinctly different degrees of sensory and behavioral complexity. Central brain tissue was immunostained with antisera raised against synapsin and alpha-tubulin. Unlike the crayfish, the stomatopod brains exhibited regular columnar organization of the central body. Furthermore, the stomatopod CXs featured noduli, globular paired neuropils that had previously been observed only in winged insects. Future experiments will incorporate dye injections and electrophysiological techniques to identify the intrinsic, afferent, and efferent neurons of the stomatopod CX.

91.5 CHOU, H*; PATHMASIRI, W; SUMNER, S; BUCHWALTER, D; North Carolina State Univ., Raleigh, RTI International, Research Triangle Park; *hchou2@ncsu.edu*

Linking Physiological Mechanisms to Thermally Driven Life History Outcomes in the Mayfly Neocloeon triangulifer

Aquatic insects play critical roles in freshwater ecosystems and temperature is a fundamental driver of species performance and distributions. Life history data of mayfly *Neocloeon triangulifer* show that this species generally follow the temperature size rule, resulting in shorter development time, smaller body size and less fecundity at higher temperatures. However, the physiological mechanisms underlying these thermal effects remain unclear. Published research suggests thermal limits are driven by the mismatch between oxygen supply and demand in the tissues of ectotherms. We tested this hypothesis by rearing the mayfly *Neocloeon triangulifer* from newly hatched eggs to adulthood at 2 °C intervals ranging from 14 °C to 28 °C. Larvae reared at 30 °C failed to reach adulthood. We then attempt to link physiological processes to life history outcomes by studying gene expression and metabolomics in mature larvae reared at different temperatures. Quantitative PCR results show that hypoxia responsive gene *EGG LAYING DEFECTIVE 9* did not respond to long term thermal challenge, whereas genes that were thermally responsive (*HEAT SHOCK PROTEIN 90, 40*) or involved in the insulin signaling pathway (*INSULN RECEPTOR, TARGET OF RAPAMYCIN 1*) were significantly increased. Metabolomics data showed that some amino acids and acylcarnitine were negatively associated with temperature. Together, these data suggest that the thermally driven life history outcomes are more likely due to energetic challenges and maintenance costs rather than oxygen limitation.

78.6 CHOU, H; FUNK, D; BUCHWALTER, D*; North Carolina State Univ., Raleigh, Stroud Water Research Center, Avondale; *dbbuchwa@ncsu.edu*

Keep Breathing: Linking Respiration to Thermally Regulated Life History Outcomes in the Mayfly Neocloeon triangulifer

Aquatic insects are widely used as indicators in freshwater ecosystems, but we know little about how temperature dictates performance and limits within and across species. Oxygen limitation (the mismatch between oxygen supply and demand) has been proposed as the primary mechanism that determines thermal limits, but the concept has not been adequately assessed in aquatic insects. We used rearing studies to establish thermal reaction norms in mayfly *Neocloeon triangulifer* in combination with respirometry studies to ask if the oxygen limitation hypothesis is supported in this species. Larvae were reared from newly hatched eggs to adulthood at 2 °C degrees interval from 14-28 °C, though 30 °C prevented larvae from reaching adulthood. This species follows the temperature size rule, with warmer temperatures resulting in smaller, less fecund individuals. Respiration rates measured from larvae reared across different temperatures show a positive relationship between oxygen consumption and larvae weight. This positive relationship becomes stronger with increasing temperature, suggesting there is a cost of growing bigger at higher temperatures. However, there is no indication that oxygen is limiting to 30 °C larvae. In fact, we observed a 2-fold increase in respiration rates between ecological (30 °C) and acute thermal limits (37 °C in our experiment), suggesting that larval oxygen consumption is commensurate with demand at ecological (chronic) thermal limits. Increasing metabolic costs appear to limit body size in thermally challenged mayflies, but oxygen does not appear to be limiting at chronic thermal limits.

115.2 CHOUINARD-THULY, L.*; REDDON, A.R.; LERIS, I.; EARLEY, R.L.; READER, S.M.; McGill University, McGill University, Utrecht University, University of Alabama; *laura.thuly@gmail.com*

Developmental experience affects habituation to a mild stressor in female but not male guppies

The stress response is an integrated set of behavioural and physiological changes that allow animals to respond to challenges in their environment. Individual variation in the dynamics of the stress response is a key aspect of an individual's phenotype, affecting its interaction with the environment. Experience of stressors during ontogeny is known to influence adult stress responses, which are physiologically mediated in part by the glucocorticoid hormone, cortisol. While there are examples of single stressors early in life affecting adult phenotypes, much less well understood is the effect of multiple interacting stressors during development, or how developmental responses differ between the sexes. We reared juvenile guppies of both sexes in a 2x2 design under either standard or high social housing densities, combined with the exposure to either cues of predation risk or to a control non-predator. We collected water-borne cortisol twice, first to measure initial release during a stressful event, and second to measure the change in cortisol released over time in response to a recurring stressor. We found that the sexes differed considerably in their physiological response to stress, with males releasing more cortisol for their body mass than females, and with females, but not males, reducing cortisol release over time. However, females reared at high rearing density and exposed to predation cues during early life did not habituate to the recurring stressor, suggesting that developmental experiences interact to shape the stress response. Our results emphasize the importance of studying multiple interacting factors and both sexes for studies aimed at understanding development of the stress response.

P3.254 CHOW, B*; COHEN, CS; San Francisco State University; *bensonc@mail.sfsu.edu*

Growth Rates of the Earliest Juvenile Stages of the Sessile Marine Invertebrate: Botrylloides violaceus

The earliest, newly settled juvenile stages are a critical phase in the life cycles of sessile marine invertebrates. Individuals must grow quickly to avoid lethal predation, yet they may be stuck in low flow boundary layers where obtaining food for rapid growth is challenging. Colonial marine invertebrates such as ascidians, cnidarians, and bryozoans, all grow via the addition of replicated small filtering units however particle capture mechanisms differ among these taxa. Ascidians with internal filters are comparatively understudied in early growth rate dynamics. Here, early growth of a highly successful invader the colonial ascidian, *Botrylloides violaceus*, is compared across habitats with characterized environmental variation (temperature, salinity, food availability, and flow rate). Newly settled zooids growing with little to no competition on PVC plates were measured initially every 2-7 days for over a month to estimate rate changes through early colony establishment. Growth rates, measured as surface area and zooid counts, showed increased rates over the 5 week period in 3 habitats. Zooid addition rate changes were observed to occur roughly around the 3rd day (3-5 zooids) and 10-14 days (10-15 zooids) with some exceptions. Surface area rate changes were often observed to occur roughly around 10-14 days and 22-23 days post settlement, as two separate rate increases. Variation around this pattern included additional rate changes observed among sampling intervals or a longer time interval to the first rate increase. Overall, this data may be used to consider if the most successful invaders show a growth rate advantage particularly at the earliest and most vulnerable stages in the life cycle.

P1.199 CHUKWUEKE, CS*; LIBBY, T; SPONBERG, S; Georgia Institute of Technology, University of California, Berkely; *cchukwueke3@gatech.edu*

Muscle's non-linear perturbation responses depend on underlying stride frequency

The diverse function of muscle during locomotion is now well appreciated, but determinants of functional changes remain elusive. While characterization of muscle function has moved from quasi-static to periodic conditions via workloops, function is still characterized primarily in unperturbed conditions. The Hill muscle model uses strain, velocity, and activation to predict force, but fails to predict history-dependent effects like shortening deactivation, which may play a larger role in functionality during perturbed or unsteady locomotion. To examine how nonlinearity and history-dependence could affect muscle function under perturbed conditions we modified the workloop approach to incorporate perturbations and replicated unsteady conditions in a fast-running cockroach, *Blaberus discoidalis*. We imposed cyclic oscillation consistent with running kinematics across the natural speed range (1-15 Hz) and added sinusoidal perturbations, either by superposition or by removing the underlying cycle so that the parameters of the Hill model were exactly matched during the perturbation even at different cycle frequencies. We found a non-linear effect of the underlying locomotor frequency on force and mechanical work production in the muscle whose effects could not be accounted for by passive material properties of the intact joint. In the Hill-type conditions we discovered a systematic increase in dissipation with frequency during swing phase perturbation and decrease in dissipation during stance phases. These results are consistent with limb perturbation studies that showed a more rapid perturbation recovery during swing at higher limb frequencies. Frequency dependent perturbation responses in muscle may be an integral part of adjusting neuromechanical control to changing speed.

P2.45 CHUNG, AK*; REEDY, AM; COX, CL; COX, RM; Georgia Southern University, University of Virginia; *ac10578@georgiasouthern.edu*

Testosterone, Energetics, and the Regulation of a Social and Sexual Signal in Brown Anoles

Because social and sexual signals often influence fitness, they receive substantial energetic investment and can be sensitive to the energetic status of an individual (i.e., condition-dependent). Understanding whether signal expression and energetics are regulated by the same mechanisms and whether signal expression is energetically limited is crucial for understanding the evolution of these traits. In this study, we used surgical castration and testosterone replacement in adult male brown anoles (*Anolis sagrei*) to understand the regulation and energetics of the dewlap, a social and sexual signal of anole lizards. We separated male anoles from a wild population in The Bahamas into three treatment groups: 1) castration surgery and a blank implant (CAST), 2) castration surgery and a testosterone implant (CAST + T), or 3) sham surgery and a blank implant (CON). Lizards were released, recaptured after two months, and measured for dewlap size and color, wet mass of fat bodies, and body condition (i.e., residuals of mass on length). We found that dewlaps were larger and darker (lower saturation and brightness) in both CON and CAST+T males compared to CAST males. Males with endogenous or exogenous testosterone (CON and CAST+T) also stored significantly less fat than CAST males. However, neither fat mass nor body condition was significantly correlated with dewlap size or color within any treatment group. Though our results do not directly link dewlap expression to energetic state, they indicate that both energetics and dewlap expression are regulated by a common hormonal mechanism.

64.3 CIERI, RL*; MORITZ, S; BRAINERD, EL; University of Utah, Brown University; *bob.cieri@gmail.com*

Ventilatory rib kinematics in the savannah monitor, Varanus exanthematicus : an XROMM study

Rib motions are important for both ventilation and locomotion in squamates. Squamate vertebral ribs are unicapitate, permitting three degrees of rotation between the ribs and vertebral column. In this study, X-ray Reconstruction of Moving Morphology (XROMM) was used to quantify rib rotations in 3 individuals of *Varanus exanthematicus* during ventilation. These rotations are composed of bucket-handle rotation about a dorsoventral axis, pump-handle rotation about a mediolateral axis, and caliper motion about a rostrocaudal axis. Our data suggest a functionally tripartite rib arrangement in *V. exanthematicus*: the vertebral ribs did not deform relative to the main shaft of each sternal rib, but the thin dorsolateral segment of each sternal rib moved relative to both the vertebral rib and the main shaft of the sternal rib during each breath. In deep breathing in standing and prone lizards, vertebral rib motion consisted mainly of equal parts bucket and pump handle motions. In the sternal ribs, by contrast, all three rotations contributed to ventilation with bucket handle rotation the most dominant and caliper the least dominant motion. Compared to deep breaths, shallow breaths consisted of significantly less vertebral rib bucket-handle rotation. The vertebral ribs also exhibited a greater degree of bucket handle rotation in prone breaths compared to standing. These differences may help to explain the evolution of unrestrictive costal joint anatomies in Squamata, with this joint design permitting variations in ventilatory and locomotor motions under different conditions and postures. We found most of the ribs of *V. exanthematicus* to move during ventilation, unlike in iguanas. These differences in ventilatory kinematics may reflect differences in locomotor strategies or lung design between *Iguana* and *Varanus*.

P2.193 CIESIELSKI, NL*; FURIMSKY, MM; Westminster College - Pennsylvania; *ciesnl22@wclive.westminster.edu*

Effects of Ammonium Nitrate and Nonylphenol on Amphibian Embryo Development

Amphibian populations have been declining around the World for several decades, with one of the primary reasons being environmental pollution. One source of pollution is agricultural activity, since pesticide and chemical fertilizer run-off can enter natural aquatic environments. We used the African clawed frog *Xenopus laevis* as our model organism to examine the effect of pesticides (nonylphenol) and fertilizers (ammonium nitrate) on developing amphibians. We hypothesized that ammonium nitrate and nonylphenol will interfere with development when embryos are exposed to sub-lethal concentrations, and that the two chemicals in combination will have an exaggerated affect compared to each chemical alone. Embryos were exposed to a range of concentrations of ammonium nitrate (0mg/L, 12.5mg/L, 25mg/L, and 50mg/L) and nonylphenol (5μM, 10μM, and 20 μM) both independently and in combination and development was monitored by examining stage specific morphology and by measuring total body length and head width. The mortality observed varied between the concentrations but when exposed to higher concentrations the embryos had delayed growth and were much smaller compared with the control and lower concentrations of ammonium nitrate. This lab study modeled a situation that can occur in natural ecosystems, and demonstrated how commonly used chemicals can potentially impact amphibian populations in the wild.

144.2 CIRINO, LA*; MILLER, CW; Univ. of Florida; *lacirino@ufl.edu*

Effects of male quality and territory quality on female preference of varying condition

Females make decisions about mates based on both direct and indirect benefits, including mate and territory quality, respectively. Female preference may change depending on the interactions between mate and territory quality, and may also be dependent on female condition. Here, we use the leaf-footed cactus bug, *Narnia femorata* (Hemiptera: Coreidae) to understand how male quality and territory quality impact female mating preferences when mating status and age vary. Female *N. femorata* of any mating status and age regularly encounter males and territories of different quality under natural settings, which may affect mate choice and ultimately the strength of sexual selection. We show differences in territory preference depending on female age, regardless of mating status. Our study indicates that 1.) female territory preference changes depending on the presence of a male, and 2.) female preference for male quality is stronger than their preference for territory quality, but only when they are in their egg-laying prime. Our results suggest that female condition may influence female mating preferences and may weaken the strength of sexual selection in the field.

P1.262 CLARK, CJ*; MISTICK, E; UC Riverside; *cclark@ucr.edu*
Hummingbird wing trill production over a range of flight speeds
Hummingbirds are famous for the hum of their wings in flight. In addition, males of some species produce a high-frequency sound, the wing trill, with modified wingtip feathers. As the kinematic basis for these sounds is unclear, we sought to characterize how these sounds vary over a range of flight speeds. We flew male Allen's hummingbirds in our new acoustic wind tunnel, which is a blower-style tunnel with an open working section that makes placing microphones outside of the flow feasible. We filmed them with two high-speed cameras and two "acoustic cameras", a device that spatially maps sound sources onto a camera image. We tested (1) whether trill amplitude varies with airspeed of the wingtip, and so becomes louder at higher flight speeds; and (2) how the orientation of the sound field varies with speed, given that the change in orientation of the flight stroke from near horizontal (hovering flight) to near vertical (fast forward flight). Our results have implications for how these sounds may be used in communication.

35.5 CLARK, J. L.*; MOORE, P. A.; Bowling Green State University; *jeslcla@bgsu.edu*
The Sensory Mechanisms of Crayfish (Orconectes rusticus) used in Detecting Predatory Threats
In order to survive organisms must be able to detect the presence of potential threats in their environment. Individuals rely on sensory mechanisms to identify certain cues, such as chemical, mechanical and visual, generated by predators. Various studies suggest that aquatic animals, including crayfish, typically rely on chemical cues to evaluate potential predatory threats. This study focused on the extent to which prey use chemical, mechanical, and visual cues to detect predators and whether the reliance on mechanisms is altered across different sensory environments (such as flow vs non-flow habitats). To study the importance of sensory mechanisms in aquatic rusty crayfish, *Orconectes rusticus*, two sensory mechanisms (visual and mechanical, visual and chemical, or chemical and mechanical) were selectively lesioned leaving the remaining mechanism (chemical, mechanical, or visual) functional. Each crayfish was then exposed to a predatory largemouth bass, *Micropterus salmoides*, in either a flowing or non-flowing stream where their behavior was recorded for thirty minutes. A 2 x 4 fully factorial MANOVA, followed by a Fisher LSD post - hoc test, showed differences in behavior between the different lesions and environments. The results show crayfish are more responsive to predatory threats in flowing streams when all of their sensory mechanisms are intact.

138.6 CLARK, EG; Yale University; *elizabeth.g.clark@yale.edu*
3D Imaging Reveals the Functional History of the Ophiuroid Arm
Brittle stars (Class Ophiuroidea), the most motile group of echinoderms, have evolved a quick, agile and effective form of locomotion in which coordinated arm movements are executed by powerful musculature and complex joint articulations. Little is known regarding the evolutionary steps involved in the development of this form of locomotion from relatively slow-moving ancestors. Ophiuroids originated in the Ordovician, yet the morphology of the modern ophiuroid arm did not emerge until the evolution of the crown clade in the Late Paleozoic. The arm morphology of stem ophiuroids is fundamentally different to that of the crown, particularly with regard to soft tissue morphology and the arrangement of the ossicles hosting the muscle/joint interfaces. The functional importance of these differences has not been tested. In order to examine the derivation of ophiuroid locomotion, the significance of this disparity needs to be assessed. We analyzed the functional implications of stem/crown differences in arm morphology using skeletal morphology and preserved and inferred soft-tissue organization. Novel insights regarding the water vascular system (WVS) in Paleozoic ophiuroids are based on a micro-CT scan of exceptionally preserved (pyritized) WVS structures in a specimen of Protasterina flexuosa from the Upper Ordovician Kope Formation of Kentucky, USA. Muscle architecture of Paleozoic ophiuroids was reconstructed based on the skeletal microstructure of isolated arm ossicles from a stenurid ophiuroid from the Lower Carboniferous (Tournaisian) of Tournai, Belgium imaged using synchrotron tomography at the Advanced Photon Source (Chicago). The differential morphology of the skeletal structures and their functional significance was assessed using 3D modeling. These analyses provide novel insight into the functional capabilities of Paleozoic ophiuroids and greater understanding of the evolution of the ophiuroid lineage.

137.2 CLARK, RM*; ADAM, K; DARRIGADE, L; MCCUE, M; ZERA, AJ; WILLIAMS, CM; University of California-Berkeley, AgroParis Tech, St. Mary's University, University of Nebraska-Lincoln; *r11clark@gmail.com*
A Genetic Polymorphism for a Hormonal Circadian Rhythm is Associated With a Shift in Metabolic Fuel Use in Flight-Capable but not Flightless Crickets
Daily hormonal rhythms are an important part of organismal life-history adaptation, but little is known about how genetic variation in endocrine traits is linked to the organismal traits they regulate. Wing-polymorphic crickets, *Gryllus firmus*, have a well-characterized genetically-polymorphic circadian rhythm for juvenile hormone (JH), which is linked to a genetic polymorphism for flight capability. We tested the hypothesis that the morph-specific JH titer cycle is linked to metabolic preparation for flight by injecting ^{13}C-labeled nutrient tracers into flight-capable and flightless crickets at five timepoints across the circadian cycle, and measured oxygen consumption, carbon dioxide production, and metabolite oxidation rates. Respiratory quotients were higher during the day and decreased at night in both morphs. In contrast, glucose oxidation rates were acyclic in flightless crickets, but decreased at night in the flight-capable morph. These patterns suggest that the JH titer cycle in flight-capable crickets is associated with a switch in the utilization of different metabolic fuels at different times in the circadian cycle, providing a link between the genetically-polymorphic hormonal rhythm and a key trait it may regulate.

P1.124 CLAUNCH, NM*; FRAZIER, JA; ESCALLóN, C; VERNASCO, BJ; MOORE, IT; TAYLOR, EN; University of Florida, Cal Poly, San Luis Obispo, Virginia Tech, Virginia Tech; *nmclaunch@ufl.edu*

Evaluating the physiological and behavioral effects of corticosterone implants in a free-ranging ectotherm

Corticosterone (CORT) levels are often used as metrics to assess population status and health of wild vertebrates, without an understanding of the effects that elevated CORT levels can induce in a given organism, population, or species. Studies that have attempted to assess effects of CORT often employ multiple-exposure acute stressors as a proxy for chronic stress, without sustained elevation of baseline CORT. We assessed the use of CORT implants as a tool for evaluating effects of chronically elevated plasma CORT in a free-ranging ectotherm so that we could study the effects of chronically elevated CORT in an arid-adapted species that regularly experiences periods of drought and sparse prey availability. We demonstrate that CORT implants can be used to successfully elevate plasma CORT compared to a control group in a population of free-ranging Southern Pacific rattlesnakes (*Crotalus helleri*) for up to 15 days. Implantation with CORT did not affect plasma osmolality, testosterone, or defensive behavior. Interestingly, we observed increased defensive behavior with higher plasma T and in snakes with more stable daily body temperatures. Trends for higher magnitude of stress response due to lower baseline CORT and increases in body temperature between baseline and stressed samples were observed, regardless of treatment group. These results add to a paucity of literature on effects of CORT on free-ranging terrestrial ectotherms, and suggest that CORT may not greatly influence physiological and behavioral trait expression in arid-adapted ectotherms such as rattlesnakes.

55.2 CLAY, TA*; TREGLIA, ML; STEFFEN, MA; TRUJANO-ALVAREZ, AL; BONETT, RM; University of Tulsa; *timothy-clay@utulsa.edu*

Transcriptomics of salamander tail tips reveal potential biomarkers of stress.

Global biodiversity is decreasing at an alarming rate and amphibians are at the forefront of this precipice. Many amphibians are negatively responding to environmental stressors, while some like habitat loss are easily recognized, many stressors are difficult to identify. An effective means to measure stress among individuals would facilitate identification of populations that may be chronically stressed and thus at risk. Increased plasma levels of glucocorticoids are often used as an indirect measure of a physiological stress response. Many amphibians are too small to extract plasma without lethality. Techniques such as assaying water borne or excrement hormone levels have been developed as less invasive measures of stress. We provide an alternative measurement of chronic stress in wild populations based on transcriptional biomarkers of chronic stress physiology. We subjected adult male Oklahoma Salamanders (*Eurycea tynerensis*) to two different temperatures in either corticosterone solution to simulate chronic physiological stress responses or filtered water as a control for 30 days. At the conclusion of the experiment, we biopsied tail tips, an often sampled tissue for genetic analysis. Transcriptomics of tail tips revealed differential up and down regulation of genes between both treatments. The identification of these genes could provide useful biomarkers for identification of wild populations experiencing chronic stress.

53.1 CLEMENTE, C J*; COOPER, C E; WITHERS, P C; FREAKLEY, C; SINGH, S; TERRILL, P; Univ. Of the Sunshine Coast, Curtin University, Univ. of Western Australia, Univ. of Queensland; *cclement@usc.edu.au*

The private life of echidnas: using accelerometery and GPS to examine field biomechanics and assess the ecological impact of a widespread, semi-fossorial monotreme

The short-beaked echidna (*Tachyglossus aculeatus*), being a monotreme, provides a unique combination of phylogenetic history, morphological differentiation and ecological specialization for a mammal. The echidna has a unique appendicular skeleton, a highly-specialized myrmecophagous life-style and a mode of locomotion that is neither typically mammalian nor reptilian but retains aspects of both lineages. We therefore were interested in the interactions of locomotor biomechanics, ecology and movements for wild, free-living short-beaked echidnas. To assess locomotion in its complex natural environment, we attached both GPS and accelerometer loggers to the back of echidnas in both spring and summer. We found that the locomotor biomechanics of echidnas is unique, with lower stride length and stride frequency than reported for similar sized mammals. Speed modulation is primarily accomplished through changes in stride frequency, with a mean of 1.39 Hz and a maximum of 2.31 Hz. Daily activity period was linked to ambient air temperature, which restricted daytime activity during the hotter summer months. Echidnas had longer activity periods and longer digging bouts in spring compared to summer. In summer, echidnas had higher walking speeds than in spring, perhaps because of the shorter time suitable for activity. Echidnas spend, on average, 12% of their time digging, which indicates their potential to excavate up to 204 m^3 of soil a year. This information highlights the important contribution towards ecosystem health, via bioturbation, of this widespread Australian monotreme.

P1.283 CLEMMENSEN, S.F.; University of Tennessee, Knoxville; *sclemmen@vols.utk.edu*

Mechanical stress and plasticity in the Blackbelt cichlid

Trophic divergence in cichlid fish is linked to shifts in pharyngeal jaw morphology. For instance, in the Heroine cichlids of Central America, the ability to crush hard-shelled mollusks is a convergent phenotype with multiple evolutionary origins. These durophagous species often have very similar pharyngeal jaw morphologies associated with the pharyngeal jaw apparatus and some of these similarities could be due to phenotypically plastic responses to mechanical stress. We examined the durophagous cichlid *Vieja maculicauda* for differences in pharyngeal osteology, dentition, and soft tissues when exposed to different diet regimes. Here we discuss the effect on the pharyngeal jaw of varying mechanical stress without varying nutrient content.

P1.114 CLIFTON, IT*; GIFFORD, ME; University of Central Arkansas, Conway and University of Toledo, Ohio, University of Central Arkansas, Conway; *Ian.Clifton@rockets.utoledo.edu*

Phenotypic and genetic integration of morphological characters in diamond-backed watersnakes (Nerodia rhombifer)

Local adaptation cannot occur unless traits under selection have a genetic basis; therefore, it is essential to determine patterns of trait heritability. However, the evolutionary trajectory of traits is also dependent on the genetic correlations among traits, potentially leading to constraints on adaptive change. We identified four fish farms with large populations of diamond-backed watersnakes (*Nerodia rhombifer*) that specialized in the species of fish they raised (either small-bodied fish or large-boded fish). We hypothesized that snakes at farms raising large-bodied fish would likely experience stronger pressure to ingest larger prey and would adapt to this pressure with changes in relative head size. We determined that in at least one large-bodied fish farm neonate snakes had larger heads, but establishing differences in head size does not necessarily imply an adaptive response. We estimated heritabilities, phenotypic correlations, and genetic correlations among traits using a full-sibling design and determined that measured cranial characteristics were, in fact, heritable, and the among-population pattern for heritability and relative quadrate length is generally in agreement with the theoretical relationship between heritability and selection; suggesting the snakes with the longest quadrates have been selection. Within each population, the skull length and mandible are most strongly correlated with one another, both genetically and phenotypically, while the quadrate has the weakest correlations suggesting it may have fewer intrinsic constraints on adaptive change than the skull length and mandible.

41.3 CLIFTON, GT*; BIEWENER, AA; Concord Field Station, Harvard U., Bedford, MA, CFS, Harvard U., Bedford, MA; *glenna.clifton@gmail.com*

Robotic loon quantifies swimming force generation

Loons (*Gaviiformes*) are remarkable swimmers, capable of diving underwater for minutes at a time and out-maneuvering fish prey. But, unlike for other foot-propelled swimming birds, the swimming behavior and hydrodynamics of loons has never been quantitatively studied. Here, we employ a novel robotic method to accurately actuate cadaveric loon feet in 3D motions tracked from freely swimming common loons (*Gavia immer*). A load cell attached between an industrial robot and the loon foot measures lift and drag forces throughout the swimming motion. This method poses significant benefits compared to alternative current methodologies that often require small study animals and repeatable motions (i.e. DPIV) or involve using simplifying assumptions to predict fluid behavior (i.e. Computational Fluid Dynamics modeling). Using seven real feet, our robotic loon replicated swimming foot motions at 3 to 14 times slower than the real loon. Extrapolating from these trials, we find that real loons produce a maximum instantaneous force of at least 5N drag and 2.5N lift with each foot. Force generation throughout the power stroke is dominated by drag, with lift contributing up to 40% of the total hydrodynamic force at any point in time. We also find that lift develops during the end of the recovery stroke, potentially contributing to propulsion despite a collapsed position of the toes. These findings represent the most accurate experimental measurement of swimming forces produced by a freely swimming bird. By understanding how loons produce forces underwater, we can directly compare swimming strategies across the avian phylogeny and assess convergent swimming strategies within foot-based propulsion. Furthermore, we hope that future studies can use this robotic method to investigate how other animals swim.

P3.52 CLUBB, BL*; CLARK, AJ; UYENO, TA; Valdosta State University, College of Charleston; *blclubb@valdosta.edu*

An anatomical description of the feeding apparatuses in two species of hagfish

Hagfish use a poorly understood feeding apparatus that includes a protractible dental plate capable of rasping chunks of tissue for ingestion. This feeding motion is accomplished through activity of a muscular hydrostat that is used to manipulate a tooth-bearing cartilaginous basal plate. In this study, we characterize the underlying functional mechanism by comparing the muscle and connective tissue fiber organizations in the feeding apparatuses of Gulf (*Eptatretus springeri*) and Pacific (*Eptatretus stoutii*) hagfishes. We characterized the morphology of the feeding apparatuses in four Gulf and five Pacific hagfishes by using standard paraffin histological techniques. The specimens were fixed in buffered formalin, serial sections of eight-micron thickness were taken, and tissues were differentiated using Milligan Trichrome stain. We used light microscopy to examine the internal muscle and connective tissue fiber organization in order to create a three-dimensional visualization of the hagfish feeding apparatus. Our interpretation of this visualization indicates that in both species the bulk of the feeding apparatus musculature aids in retraction and hydrostatic support of the tooth plate. A comparatively smaller ventral portion is used in protraction. Preliminary results of our morphological analyses suggest that there is no significant difference in the size of the feeding apparatuses when corrected for body size differences between the two species. Within the genus *Eptatretus* the morphology of the feeding mechanism seems to be quite conserved. We are engaged in expanding our morphological descriptions of other hagfish feeding apparatuses, especially those of the genus *Myxine*, in order to assess general hagfish morphological diversity.

23.6 COCILOVA, CC*; MILTON, SL; FLEWELLING, LJ; BOSSART, GD; WALSH, CJ; FL Atlantic Univ., FL, FL Fish and Wildlife Research Inst., FL, Georgia Aquarium, GA, Mote Marine Laboratory, FL; *ccocilov@fau.edu*

The Effects of Red Tide Toxins in Turtles - Developing Treatment Protocols for Endangered Sea Turtles

The dinoflagellate Karenia brevis is a key organism present during harmful algal blooms (HABs, Red tides) which are increasing in frequency and duration worldwide. K. brevis produces a suite of neurotoxins collectively referred to as brevetoxins (PbTx). Brevetoxin binds to sodium channels which trigger a cascade of events, eventually leading to cells death. PbTx exposure affects marine life by interrupting neurological functions, decreasing immune function, and inducing inflammation. Brevetoxicosis is difficult to treat in endangered sea turtles, as the physiological impacts have not been fully investigated and the magnitude and duration of PbTx exposure is generally unknown. Freshwater turtles (Trachemys scripta) are being used as a model system for experimental toxin exposures. Analyzing uptake, tissue distribution, routes of excretion, immune function and neurological responses will give us insight into the fate of PbTx. PbTx-3 was widely distributed in all tissues and fluids of T. scripta and the toxin shows to clear within 24 hours, following both oral and intratracheal exposures. These short term exposures did not result in obvious tissue pathology. Preliminary results suggest turtle neurons are surprisingly resistant to PbTx. Cell viability decreased in a dose dependent manner across PbTx concentrations from 100-17500nM; the LC50 was significantly higher than is seen in mammalian neurons. PbTx-3 exposure resulted in significant Ca2+ influx, which can trigger a cascade of excitotoxic events leading to cell death. We are currently testing treatment strategies that can be implemented to reduce the number of sea turtle deaths from PbTx-3 exposure.

P2.155 COCKBURN, GD*; BALDWIN, MW; Max Planck Institute for Ornithology; *gcockburn@orn.mpg.de*

Characterizing sweet taste perception in the tataupa tinamou (Crypturellus tataupa) and the feral pigeon (Columba livia)

Sweet taste perception is a valuable sensory tool influencing diet choice and ecological niche. Notably, for species with a frugivorous diet, the ability to perceive sugars could provide a distinct evolutionary advantage aiding them in foraging more effectively. Many vertebrates can perceive sweet tastants; however this ability is not ubiquitous across the entire Aves clade, as a key part of the mammalian sweet receptor is lost in birds. Hummingbirds have been shown to have taste receptors to detect sugars; but whether this is true of other birds is not yet known. In this study, we investigate the taste preferences of tataupa tinamou (*Crypturellus tataupa*) and the feral pigeon (*Columba livia*) These species represent basally-branching clades - Palaeognathae and Columbaves - which contain many frugivorous species, however few studies have been conducted into taste perception in these groups. Here, using brief access video-monitored trials to control for post-ingestive effects, we examine whether *C. tataupa* and *C. livia* display a behavioral preference for sucrose. The characterization of taste preferences in basal clades, such as Palaeognathae and Columbaves, will deepen our understanding of the evolution of chemosensory perception across birds.

92.5 COHEN, KL*; PIACENTINO, ML; WARKENTIN, KM; Boston University; *kcohen@bu.edu*

Two Types of Hatching Glands Facilitate Escape-hatching of Red-eyed Treefrogs Across Multiple Contexts and Developmental Stages

Red-eyed treefrogs, *Agalychnis callidryas*, are an excellent example of environmentally cued hatching. Undisturbed, these arboreal embryos typically hatch at 6-7d, but they can hatch as early as 4d to escape pathogens, dehydration, and predators, responding to attacks in seconds. We showed that *A. callidryas* hatch by acutely releasing hatching enzyme from large hatching gland cells (HGCs) concentrated on their snout, which appear at 4d. More recently, using a strong hypoxia/flooding cue, we found that embryos can hatch at 3d, before these glands develop. Using scanning electron microscopy, we found another, earlier developing and smaller type of HGCs with a more dispersed spatial distribution. We used *in situ* hybridization to visualize hatching enzyme gene expression over development and found it matches the spatial distributions of both types of HGCs observed in SEM. Expression was also visible at stages before HGCs are externally visible, indicating that transcription begins before HGCs are fully developed. We then used histology to assess localization of the hatching enzyme mRNA in the two types of HGCs. The smaller, earlier-appearing HGCs more closely resemble HGCs observed in other hylids in their morphology, spatial distribution, and developmental timing. Thus, they may be the ancestral HGC type and the large HGCs a derived cell type that enables rapid escape from predators. *A. callidryas* is the first anuran observed to have two types of hatching gland cells, but other species with dramatic cued hatching responses have not been investigated. Our studies of another treefrog have shown that both gradual and acute release of hatching enzyme can occur in the same species in different contexts. Hatching mechanisms in anurans are clearly more diverse than previously known.

99.3 COHEN , K *; HERNANDEZ , LP; The George Washington University ; *karlyc@gwmail.gwu.edu*

Ontogeny of the Filtering Apparatus in Silver carp (H.molitirix): The Structure Behind the Invasion

Highly invasive Asian carp are destroying ecosystems throughout the United States by outcompeting native species. With populations growing at an alarming rate, these fish have proven difficult to control. Their ability to thrive within eutrophic environments is due to their very efficient filter-feeding mechanism. Here we present data from an ontogenetic series of Silver Carp ranging in size from 15-900mm SL detailing how this unique filtering structure is built. Like many filter-feeding species, Silver carp possess an incredibly large epibranchial organ that occupies the majority of the dorsal buccal cavity. Branchial arches 1-5 have greatly modified gill rakers that span both the ceratobranchial ventrally and the epibranchial as it curves into the body of the epibranchial organ. From the earliest ontogenetic stage examined individual gill rakers already show a modified shape as compared to the basal character state for Cypriniformes. As development proceeds the structure of these gill rakers becomes increasingly complex. By early juvenile stages secondary growth of bone stitches together the primary lamellae, forming a screen-like mesh upon which future elaborations of the filtering structures are built. As development proceeds the individual lamellae of gill rakers maintain their shape as they increase in height. These lamellae will later become scaffolding for more complex filtering structures. Gill rakers involved in filtering undergo significant architectural changes during development. However, those curling into the epibranchial organ undergo separate structural changes due to the morphological constraints of the epibranchial organ. Comparisons with the Bighead carp, a congeneric, suggest the Bighead morphology more closely resembles that of the basal cypriniform condition.

P2.222 COLEMAN, A/L*; LANCE, S; University of Georgia; *acolem12@uga.edu*

Drivers of Community Structure and Implications for Diversity-Disease Relationships

Global biodiversity is being lost at an alarming rate due to anthropogenic activities. Concurrently, emerging infectious diseases affecting both wildlife and human populations are becoming an increasing concern implying that biodiversity and infectious diseases are linked. The dilution effect suggests that more diverse communities constrain pathogen infection due to an increase in abundance of incompetent host species. We aim to explore the relationship between amphibian community structure and dynamics of two infectious diseases- Ranavirus (RV) and *Batrachochytrium dendrobatidis* (Bd). Previous studies suggest a dilution effect for amphibian diseases, but were conducted in areas with low host diversity. Our study site is the U.S. Department of Energy's Savannah River Site in South Carolina. The SRS contains 100's of wetlands and over 30 species of pond-breeding amphibians. In addition, preliminary surveys indicate widespread occurrence of RV and Bd. In order to investigate the relationship between amphibian biodiversity and disease, we first need to 1) characterize the amphibian communities of wetlands and 2) examine the drivers of amphibian communities. From January to July of 2016, we surveyed and gathered amphibian community data for 20 ephemeral wetlands of varying hydroperiods. Wetlands were sampled monthly using standardized dipnet and minnow trap transects. Greater than 20,000 individual amphibians were captured and documented across 23 species. We used Akaike Information Criteria and the top models for explaining the Chao 1 species richness index all included some combination of sampling time, wetland group and/or hydroperiod. We are still currently investigating other environmental factors that could be important drivers of community structure.

P1.206 COLLIAS, AA*; KONOW, N; TIJS, C; BIEWENER, AA; University of Massachusetts Lowell, Concord Field Station, Harvard University, UMass Lowell, Concord Field Station, Harvard University, Concord Field Station, Harvard University; *alexandra_collias@student.uml.edu*

Muscle Fiber Length Change in Rat Medial Gastrocnemius in the Stance Phase of Galloping

The lower hind limb muscles in cursorial vertebrates have been hypothesized to be specialized for meeting the varying mechanical demands of ground-based locomotion. The mechanical action of one such muscle, the medial gastrocnemius (MG), is well studied for bipeds but less so for quadrupeds. We used fluoromicrometry to measure MG muscle fiber length changes as rats ($N = 5$) galloped on a treadmill set at different slopes (-20°, 0°, +20°). These slopes were expected to elicit different demands for force production and fiber contractile length changes as the muscle would need to act as a brake, strut, or motor, respectively. Muscle fibers were expected to lengthen and dissipate energy, acting as brake on a decline. On the level, muscle fibers were expected to remain near-isometric, letting the Achilles tendon elastically cycle mechanical energy between strides. Muscle fiber shortening was expected to be greatest on an incline, allowing the muscle to act as motor to perform mechanical work. Consistent with these hypotheses, we found that MG muscle fibers lengthened on a decline to dissipate energy in early stance and shortened on an incline. However, our results do not support the hypothesis of near-isometric contraction allowing the muscle to act as a strut during level galloping. The unexpected small amount of muscle fiber shortening on the level supports prior suggestions that the rat Achilles tendon may be overbuilt for elastic energy cycling. Fiber shortening may be necessary to produce additional work as forelimb muscles potentially dissipate energy in comparison to hindlimb muscles. Future research will aim to identify those fore and hind limb interrelationships. Funded by NIH AR055648 to A.B.

P1.3 COLLIN, R*; FREDERICQ, S; FRESHWATER, DW; MASLAKOVA, S; MIGLIETTA, MP; ROCHA, RM; RODRíGUEZ, E; THACKER, RW; Smithsonian Tropical Res. Inst., Univ. Louisiana, Lafayette, UNC Wilmington, Univ. Oregon, TAMU, Univ. Federal do Paraná, American Museum, SUNY Stony Brook; *Collinr@si.edu*

Increasing Access to Methods in Organismal Taxonomy and Identification

One of the greatest current threats to the study of biodiversity is the loss of taxonomic expertise. As the number of experts declines, it becomes increasingly difficult to train the next generation of taxonomists as well as to disseminate knowledge of the basic methods required to study poorly known taxa. A major challenge in learning the taxonomy of marine invertebrates and macroalgae is learning the methods and "tricks of the trade" that are buried in hard-to-obtain taxonomic papers or simply unpublished. Dissemination of this information is complicated by the fact that many of the methods are best conveyed through hands-on demonstrations and in-person training. For many groups, there are few active taxonomists and in-person training may be difficult to obtain. As a first step to confront these challenges, we have developed a series of "How To" videos focused on basic techniques for collection, preservation and identification of marine organisms. Focusing on macroalgae, tunicates, sponges, hydrozoans, sea anemones and nemerteans, the six taxa represented in the Bocas NSF-ARTS project, these videos aim to help students and biodiversity researchers to prepare material that is useful for identification and taxonomic research. Associated protocols provide more detailed information on the best ways to observe the anatomy and biology of the organisms. Transcripts in both English and Spanish are provided to broaden accessibility of the information.

43.7 COLLINS, EE*; HALANYCH, KM; MAHON, AR; Central Michigan University, Auburn University; *eecollin1@gmail.com*

Phylogeography of Nymphon australe (Pycnogonida, Nymphonidae) Populations in the Southern Ocean

Pycnogonids (sea spiders) are widely distributed globally and are a speciose, basal class of chelicerates within Arthropoda. They are especially abundant and diverse in the Southern Ocean and many species are reported to have a circumpolar distribution despite their brooding reproductive patterns. *Nymphon australe* is the most commonly found species of Pycnogonida in the Southern Ocean and more than a quarter of all *Nymphon* species are present in Antarctic waters. Previous studies on the population structure of *N. australe* using two mtDNA loci have shown large-scale population connectivity patterns across three circumpolar geographic areas around Antarctica. However, recent developments using RADseq for acquisition of single nucleotide polymorphisms (SNPs) has shown the ability to investigate whole genomes for fine scale population differences. To investigate the population structure of *N. australe* on a finer scale than in previous studies, SNP data was analyzed via 2b-RAD sequencing methods from samples collected throughout the western Antarctic. We hypothesize that with the finer resolution of the SNP data from throughout the genome of *N. australe* that structure will be more defined than in previous studies using mitochondrial data alone.

12.4 COMBES, SA*; GAGLIARDI, SF; SALCEDO, MK; IWASAKI, JM; RUNDLE, DE; CRALL, JD; University of California, Davis, Harvard University, University of Otago, New Zealand, Harvard University; *sacombes@ucdavis.edu*

More Than One Way to Capture Prey: Comparative Flight Biomechanics and Capture Strategies of Hunting Dragonflies

Dragonflies are highly successful aerial predators that pursue a variety of prey, engaging in complex, three-dimensional pursuits that are typically completed in less than a second. Because mechanistic studies of aerial predation are scarce, we do not yet know whether predators employ a general kinematic and behavioral strategy when pursuing most prey, or whether they tailor their pursuit to each prey type; nor do we know how widely prey species differ in their survival strategies and in their sensorimotor capabilities. To address these questions, we examined aerial interactions between dragonflies and dipteran prey, filming hundreds of encounters with high-speed video to reconstruct 3-d trajectories, quantify flight biomechanics, and examine pursuit and escape strategies. We studied three species of libellulid dragonflies (*Libellula cyanea*, *Pachydiplax longipennis*, and *Sympetrum rubicundulum*) pursuing four species of dipteran prey. By analyzing large numbers of encounters between different predator-prey pairs, we were able to identify common mechanical features of dragonfly predation, infer which prey species can sense and actively respond to approaching predators, and pinpoint key factors that help determine the outcome of predator-prey interactions. Surprisingly, we found that two of the dragonfly species achieve similar levels of capture success and expend similar amounts of power to capture prey, but they do so using very different capture strategies: slow, stealthy approaches that prey rarely detect vs. rapid, powerful approaches that prey try to evade but rarely can. These findings highlight the importance of examining complex flight behaviors such as predator-prey interactions in a natural, comparative context.

P1.162 CONES, A. G.*; LIEBL, A. L.; HOUSLAY, T. M.; RUSSELL, A. F.; University of Exeter, Univerity of Exeter, University of South Dakota; *agc215@exeter.ac.uk*

Plasticity in embryonic heart rates in cooperative chestnut-crowned babblers

Developmental rates are now known to have defining phenotypic consequences in adulthood, leading to a need for a greater understanding of the factors affecting such rates. While measuring such rates in neonates is relatively straight-forward, we have a relatively poor understanding of the factors affecting developmental rates pre-birth. Here we investigate the factors affecting heart rate, a known associate of developmental rates, in artificially-incubated eggs of the chestnut-crowned babbler (*Pomatostomus ruficeps*), a 50g avian cooperative breeder from outback Australia. As expected, heart rates were profoundly influenced by egg-shell temperature, and to a lesser extent embryo age. However, such effects were also modified by egg volume and laying order, suggesting maternal effects have a significant influence on embryo metabolic rates. Further, we found significant temperature-mediated plasticity on heart rates, which varied among individuals. Finally, we will investigate what factors may explain that variation in plasticity of heart rate among individuals.

102.5 CONITH, MR*; HU, Y; WEBB, JF; ALBERTSON, RC; UMass Amherst, Univ. of Rhode Island; *mrconcan@cns.umass.edu*

TGFβ signaling is associated with the evolution of an exaggerated phenotype in East African cichlids

Cichlid fishes display remarkable phenotypic diversity, especially in regards to their craniofacial anatomy. One unique corner of this diversity is in the soft tissue surrounding the upper jaw. In a handful of the over 2,000 species of East African cichlids, that soft tissue has undergone severe hypertrophy, resulting in a conspicuous fleshy flap. Just beneath the surface of the flap is the intermaxillary ligament that stretches across the premaxilla to connect the right and left maxillary heads. This ligament is present in all cichlids, but in its hypertrophied form we find upon examination of histological sections that it also interdigitates with the more superficial connective tissue and anchors to the epithelium, forming a novel ligament-epithelial connection. Based on genetic/genomic mapping experiments, we identified ADAM12 as a candidate gene for flap hypertrophy. *ADAM12* has been shown to regulate tissue invasion and extracellular matrix deposition and it is an upstream regulator of *TGFβ*. *TGFβ* is a known regulator of ligament development via the tendon and ligament-specific transcription factor scleraxis. Taking advantage of this pathway, we implanted beads soaked in the *TGFβ* protein into juvenile cichlids with and without flaps. We found that this experimental manipulation resulted in an expansion of scleraxis expression, ligament hypertrophy, and concomitant changes in flap morphology. The evolution of phenotypic novelty by trait exaggeration is a common theme in evolutionary biology. Here we provide molecular inroads into the developmental mechanism through which one such trait has evolved.

P1.182 CONITH, AJ*; CRUMPTON, N; KAMILAR, JM; DUMONT, ER; Univ. of Massachusetts Amherst, University College London; *ajsmith@bio.umass.edu*

The role of phenotypic integration in the evolution of cranial morphological disparity in moles (Talpidae: Mammalia)

Most fossorial mammals converge upon similar morphologies: a slender body shape, powerful limbs, and a tapered skull to assist with movement through the substrate. Convergence in these morphologies among fossorial mammals suggests strong selective pressures for function. Phenotypic integration (degree of covariation among traits) can affect the ability of structures to respond to selection. Here we examine the link between integration and skull morphology in ambulatory and burrowing talpids. We used geometric morphometrics to characterize talpid skull shape and constructed a time-calibrated tree using previously published data. We then tested a series of evolutionary models to understand the role of selection in patterning skull shape. Talpid skull shape evolution fit a two-peak Ornstein-Uhlenbeck model with selection favouring optima for fossorial (e.g., *Talpa*) and non-fossorial (e.g., *Uropsilus*) morphologies. We then investigated differences in the level of integration and disparity between these two burrowing behaviours. We found the skulls of highly fossorial talpids occupy different regions of morphospace than those with low levels of fossorial behaviour. We also found that fossorial talpids exhibited high levels of morphological integration whereby the rostrum and braincase regions covary tightly, while ambulatory talpids were more modular with rostrum and braincase regions that vary independently. However, ambulatory and fossorial talpids exhibited equivalent levels of disparity. Despite their high skull integration, fossorial moles have diversified quickly, and exhibit a worldwide distribution despite their specialized niche.

P3.91 COOMES, C.M.*; WILSON, N.K.; DANNER, R.M.; DERRYBERRY, E.P.; Tulane University, University of North Carolina Wilmington; *ccoomes@tulane.edu*

Does Thermal Stress Affect Mate Selection?

Climate change is a global trend creating new evolutionary pressures for existing species. With climate change comes an increase in the number and length of heatwaves. These periods of increased temperatures can induce thermal stress in organisms. Many of these heatwaves have caused large mortality events in birds. While some studies have addressed the lethal effects of high temperatures on endotherms such as birds, relatively few have addressed sublethal effects. Recent research has shown that sublethal thermal stress can negatively influence cognition in zebra finches (*Taeniopygia guttata*). We hypothesize that thermal stress can affect an organism's ability to select mates due to reduced motor and cognitive ability. Female birds often select mates based on the quality of males' song. We predict that female birds will put less effort into selecting a mate while under thermal stress than at ambient temperatures, as well as discriminate less between favorable and unfavorable songs. To test this, we used operant conditioning on female zebra finches, with a choice between conspecific and heterospecific songs. Our findings suggest that most females under heat stress will invest energy into mate choice but may not be as discriminating. We discuss our results in the context of associated fitness costs under current and future climate conditions.

P1.201 COOPER, AN*; CUNNINGHAM, CB; MORRIS, JS; POTTS, WK; CARRIER, DR; University of Utah;
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Muscle Mass Distribution and Social Dominance in Male House Mice

Intense physical competition between males for access to mating opportunities is widespread among mammals. In such agonistic encounters, males with a combination of morphological and behavioral characters that allow them to dominate an opponent often have greater reproductive fitness. However, the specific physical traits that facilitate social dominance are poorly understood. Body size is often correlated with reproductive fitness in mammals. Interestingly, body mass only weakly predicts fitness in male house mice (*Mus musculus*). We hypothesized that muscle mass and distribution influence dominance status. Greater muscle mass is associated with (1) larger muscle cross-sectional area, which provides an increased capacity for force production, and/or (2) longer muscle fascicles, which allow for a faster contraction. Therefore, individuals with relatively larger muscle mass may be capable of producing more power, permitting them to more easily manipulate an opponent. To understand which muscles are most important when mammals fight, we compared the mass of 10 major muscle groups in a set of 9 dominant and 20 non-dominant male mice. House mice are appropriate organisms to study social dominance because they possess a polygynous mating system where males compete physically to gain access to territory and, thus, access to females. As expected, extensor muscles of the forelimb and distal forelimb muscles were found to be larger in dominant males. However, our results were only partially consistent with our expectations. For example, muscles of the neck from the trapezius and sternocleidomastoid complexes did not differ based on dominance status. These results suggest that our current conceptualization of mammalian dominance behavior may be incomplete.

13.5 COOPER, W J*; CARTER, C; MCMENAMIN, S; SWEET, E; GALINDO, D; WAGNER, M; NAZAIRE , C; KHALID, A; Washington State University, Tri Cities, University of Massachusetts, Lowell, University of Massachusetts, Lowell;
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Evo-Devo studies identify metamorphosis a critical period for determining jaw protrusion mechanics in both acanthomorph and cypriniform fishes

The ecomorphology of fish feeding is an intensely studied area of functional morphology and comparative biology. This body of work has identified jaw protrusion as an innovation that has promoted massive diversification in multiple lineages. Two of these, the Acanthomorpha and Cypriniformes, account for approximately one third of living vertebrates. We performed phylogenetic comparative analyses of jaw protrusion kinematics and cranial morphology in species-rich families from each clade and found jaw protrusion to have undergone extensive evolution in both. Alterations in protrusion ability were significantly related to shifts in feeding niche and protrusion performance is predominantly determined by upper jaw morphology, particularly the length of the ascending arm on the premaxilla, which is an anatomical structure that has evolved convergently in both lineages. To better understand the development of protrusion mechanics we performed kinematic and morphological studies of the orange clownfish (Pomacentridae; Acanthomorpha) and the zebrafish (Cyprinidae; Cypriniformes) using extensive developmental series of each. Our results show that protrusion ability manifests late in development and is strongly associated with metamorphosis and remodeling of the skull during the larval to juvenile transition. This work indicates that studies of skull metamorphosis have the potential to illuminate the developmental underpinnings of evolutionary success in an extensive portion of the vertebrata.

65.1 COPPENRATH, C/M*; LASALA, J; MEERSOHN, N; BALDWIN, J; Florida Atlantic University;
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Characterizing the foraging ecology and migratory movements of Atlantic leatherback turtles (Dermochelys coriacea) via stable isotope analysis and mitochondrial DNA

North Atlantic leatherback turtles (*Dermochelys coriacea*) undertake extensive migrations between highly productive foraging habitats in northern latitudes and nesting beaches in tropical and subtropical latitudes. While this migratory behavior has been documented in the wider Caribbean, the migratory movements of the leatherbacks nesting in South Florida are relatively understudied. Florida's nesting population of leatherback turtles has increased 10.2% on average per year since 1979, yet little is known about the migrations to and from foraging habitats for this population. Recent research suggests that these individuals may be at an increased risk of interactions with coastal shrimp fisheries during internesting and post-nesting movements. Here, we analyzed $\delta^{13}C$ and $\delta^{15}N$ stable isotopes in whole blood in order to gain insight into the foraging ecology of the leatherback turtles nesting in South Florida and compared those data to previous studies in the Atlantic. We also tested whether the observed isotopic signatures were correlated with mtDNA haplotypes to examine the relationship between migratory foraging behavior and nesting site fidelity.

P1.185 CORBIN, KM; Stony Brook Univ.;
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Turbinal variation in Lontra canadensis

Turbinals are thin bones in the nasal cavities of mammals. Carnivoran turbinals originate from the maxillae, nasal, ethmoid, and frontal. Maxilloturbinals (MTs) function in respiration, preventing heat and water loss by conditioning the air in the nasal cavity. Ethmoturbinals (ETs) are located in the posterior nasal cavity and function in olfaction. This study seeks to determine if there is a relationship between MT density and latitude. Heat loss risk is higher in colder climates, thus MT density between individuals is expected to vary with climate. I predicted MT density, scaled using skull length or ET density, would positively correlate with latitude. ETs were used as a control because olfactory demands are not expected to vary by latitude. North American river otters, *Lontra canadensis*, were chosen for this study because the species has a broad geographic range, from Nunavut to Florida. *Lontra* skulls were micro-CTed and 3D models of rectangular prisms from MTs and ETs were segmented. Turbinal surface area (SA) was calculated for MTs and ETs and scaled by skull length or each other to account for allometry and/or differences in scan quality. Scaled values were compared to latitude using correlations and regressions in R. As predicted, there was no relationship between scaled ET SA and latitude. The results indicate a slight relationship between the ratio of MT to ET and latitude, indicating relative turbinal density within an individual may be important for temperature regulation. There was no relationship between scaled MT SA and latitude. This may be due to gene flow, where strong selection for dense turbinals at high latitudes overpowers selection for less dense turbinals at low ones. Alternately, dense turbinals may have little evolutionary cost in warm climates. A final possibility is the limited geographic range of the sample hindered detection of any effect.

P2.113 CORDER, KR*; STORMSHAK, F; Oregon State University; *keely.corder@gmail.com*
Activation of Rapid Signaling by Estrogen in the Ovine Endometrium
Classical estrogen effects occur via nuclear receptors, but many known effects of estrogen are inconsistent with classical pathways. Recently, research has focused on non-genomic rapid effects of estrogen, mediated by receptors in the plasma membrane and second messengers. An experiment was conducted to determine if estrogen initiates rapid signaling events in the ovine endometrium by examining the effects of 17β-estradiol on the activation of phosphatidylinositol hydrolysis (PIP2/DAG pathway). Endometrial tissue was collected from four Polypay ewes on day 8 of the estrous cycle and incubated with tritium-labeled myo-inositol for 90 minutes followed by treatment with 17β-estradiol (10 nM) or vehicle for an additional 30 minutes. Statistical analysis revealed a significant activation of the PIP2 pathway by 17β-estradiol, evidenced by an increase in the incorporation of tritium-labeled myo-inositol into inositol phosphates. These preliminary data suggest rapid actions of estrogen may be mediated by activation of the PIP2 signaling cascade via estrogen receptors in the plasma membrane.

48.4 CORN, KA*; BEMIS, WE; University of California, Davis, Cornell University; *kacorn@ucdavis.edu*
Tooth Microstructure, Development, and Replacement in the Sharpnose Sevengill Shark, Heptranchias perlo
Characters based on tooth microstructure and tooth development have been included in phylogenetic studies of sharks (Chondrichthyes: Elasmobranchii: Selachii), but many critical details have not been compared as closely as needed. We used histology and micro-CT scanning to study tooth morphology and development in the Sharpnose Sevengill Shark (Hexanchiformes: Hexanchidae: *Heptranchias perlo*) using the same methods we previously used to study the Blue Shark (Carcharhiniformes: Carcharhinidae: *Prionace glauca*) and the White Shark (Lamniformes: Lamnidae: *Carcharodon carcharias*). We found that the Sharpnose Sevengill Shark has relatively few rows of replacement teeth, which is similar to the Blue Shark, but that that the fully developed teeth are composed primarily of osteodentine and lack a well-developed pulp cavity. This condition, categorized as osteodont, also occurs in lamniform sharks such as the White Shark. A low number of rows of replacement teeth suggests that tooth replacement rates are relatively slow, which could be correlated with factors such as diet or metabolism. But it is striking that the Sharpnose Sevengill Shark and White Shark have similar tooth microstructure, for they are only distantly related. As yet, we do not have an explanation for this apparently convergent condition in tooth microstructure.

104.2 CORNELIUS RUHS, E*; VEZINA, F; KARASOV, W; University of Wisconsin-Madison, Universite du Quebec a Rimouski; *ecornelius@wisc.edu*
Do differing levels of food supplementation alter body composition and immune function in a wild residential bird?
In winter and during extreme weather events, natural food abundances may sometimes not be adequate. This unpredictability in resources might then have a negative impact on immune function, as would occur if acquired energy is diverted towards gaining fat and away from maintaining immunity. To test this idea we compared immune function and body composition of three groups of wild black-capped chickadees (Poecile atricapillus) that were given either continuous or intermediate levels of food supplementation or non-food supplemented. Continuously supplemented birds were captured at locations where bird feeders were present and consistently filled from November-March. Intermediately supplemented birds were captured in locations where food was provided from Nov-Jan and then food was removed. Unsupplemented birds were captured at locations where bird feeders were not present. Throughout the course of the study we examined multiple aspects of the immune system (constitutive and induced), body mass, fat and muscle score. Intermediately supplemented birds had higher initial capture fat scores compared to unsupplemented birds. At initial capture, all birds had similar masses; however, continuously supplemented birds had slightly lower muscle scores compared to intermediately supplemented birds. Birds in all groups mounted a similar fever response (change in temperature) to injection with lipopolysaccharide; however, continuously supplemented birds lost slightly less mass after injection compared to the other two groups. Results from this study demonstrate that during times of variable and uncertain food availability, like extreme weather events or long winters, birds are able to buffer themselves against this uncertainty by increasing fat mass, which may in turn impact aspects of the immune system.

75.3 CORNELL, A*; GILLESPIE, C; SEROTA, M; WILLIAMS, TD; Simon Fraser University; *acornell@sfu.ca*
Introduction of new prey to a specialist predator: diet preferences and reproductive consequences
During the early stages of development, diet is known to affect the growth of individuals and subsequent quality of adults. Therefore, parents' dietary choices during provisioning of young may influence fitness of their offspring. With regular biotic and abiotic changes in the environment, parents must adjust their dietary selections to maximize fitness. Many studies have explored the theoretical or lab-based consequences of different diet choices with hypothetical environmental changes, but less often in the field. We took advantage of an accidental human introduction of black solider flies that occurred on our long-term field site in 2015. Our study system includes ~60 breeding pairs of free-living European starlings (*Sturnus vulgaris*), which provision their young for 21 days before the chicks fledge. We use data from 2 years prior to new prey introduction and 2 years post introduction to understand how diet shifted with environmental change. We also test effects of diet choices on the number (total chicks fledged) and quality of the chicks. Preliminary analysis shows that starling predators were tipulid larva (*Tipula paludosa* and *Tipula oleracea*) specialists prior to the introduction: 40-60% of prey items brought back to the nest were tipulids in 2013 and 2014. After introduction in 2015, 65% of the prey items were black-soldier flies, though some individuals persistently provisioned tipulids to their young. We explore the differences in meal content of predators and the effects of the offspring quality and number to understand how changes in the environment affect dietary choices of parents caring for young, and the consequences on offspring.

77.6 CORYELL, RL*; NISHIGUCHI, MK; NMSU; *coryellr@nmsu.edu*

Temperature adaptation influences symbiont specificity in an experimentally evolved bobtail squid-luminous bacterium association

Marine bacteria encounter a myriad of abiotic factors that can influence survivability and adaptation. Specifically, bacterial symbionts that are environmentally transmitted have dual roles that select for both phenotypic and genetic adaptations that influence survival in the planktonic as well as the symbiotic state. Host animals may shift their native range in response to changing local environmental conditions like temperature, while free-living symbionts need the ability to either migrate with their native hosts or infect novel hosts that are found in their geographical range. The sepiolid squid-Vibrio symbiosis has been a tractable model to examine abiotic factors that influence environmental trade-offs that Vibrio bacteria are subject to while outside the squid. We used an experimental evolution approach to investigate whether adaptation to specific environmental conditions (e.g. temperature) increased the ability of symbiotic bacteria to accommodate new hosts from different geographic areas and temperature regimes. Using physiological measures associated with bacterial ability to initiate and maintain symbiosis (bioluminescence, colonization, growth, biofilm formation), we compared ancestral to evolved strains from a number of Indo-west Pacific populations to determine whether temperature increases the ability of *V. fischeri* to expand their host range. Furthermore, infection assays indicate that the ability to colonize a novel host by strains from a different geographic origin and host squid is influenced by the temperature regime at which they were evolved, indicating that environmental factors shape symbiont colonization and fitness. Results from this study will provide a better understanding of whether adaptation to abiotic fluctuations affects holobiome fitness, and will give insight to the degree at which climate change influences beneficial associations.

P1.207 COUGHLIN, DJ*; SHUMAN, JL; BRADLEY, MA; COUGHLIN, David; Widener University; *djcoughlin@widener.edu*

Thermal acclimation and gene expression in rainbow smelt, Osmerus mordax

Rainbow smelt, *Osmerus mordax*, have an impressive ability to acclimate to very cold water. These fish express both anti-freeze proteins and glycerol in their plasma, liver, muscle and other tissues to avoid freezing at sub-zero temperatures. Muscle contractile properties in smelt are also dramatically affected by cold exposure - cold-acclimated fish have faster contractile properties of both red and white muscle and are capable of faster swimming speeds. We used RNA-Seq and qPCR to examine gene expression in smelt muscle to determine the genes responsible for the thermal acclimation response in these fish. A pilot transcriptome analysis indicates substantial differences in gene expression between red and white muscle fiber type and between cold and warm acclimated fish. qPCR confirms differences in the expression of genes associated with both metabolic and muscle function and thermal acclimation. Data will be presented on recent RNA-Seq experiments.

102.3 COUNTERMAN, BA*; VAN BELLEGHEM, S; SHAAK, SG; YEAGER, J; Mississippi State University, University of California, Merced; *bcounterman@biology.msstate.edu*

Hybridization and the origin of novel warning coloration in Heliconius butterflies

Hybridization between divergent races and species can produce an amazing diversity of novel forms. However, for these novel recombinant forms to become established, they need to encounter ecological settings in which they are sufficiently fit. In *Heliconius* butterflies, genetic changes at only a handful of color patterning genes have generated a variety of distinctly colored geographic races that form narrow hybridization zones maintained by strong selection. Using whole genome data, we demonstrate that hybridization between the divergently colored races of *H. erato* in the Guiana shield, *H. e. hydara* and *H. e. erato* has resulted in a recombinant phenotype that has become established as a stable population, called *H. e. amalfreda*, approximately 0.9-1.2 Mya. The *H. e. amalfreda* wing color pattern originated from introgression of a 7 kb *H. e. hydara* region into the *H. e. erato* genomic background near the gene *optix*. This region likely affects the spatial expression of red pigmentation and contains a block of recently active transposable elements that are perfectly associated with absence of red hindwing rays in *H. e. amalfreda*. By releasing the *H. e. amalfreda* form in a hybrid zone where it is not natively present, we demonstrate that individuals with a novel, hybrid warning coloration can have regionally high survivorship, similar to the parental races. This is in agreement with frequency-dependent selection, imposed by predators that learn to avoid these signal, which favors hybrid phenotypes in areas where rates of hybridization are high. These results show how genomic admixture and selection dynamics in hybrid zones can lead to the establishment of novel adaptive forms.

68.1 COURANT, J*; SECONDI, J; BEREIZIAT, V; HERREL, A; Centre National de la Recherche Scientifique, Université d'Angers; *jcourant@edu.mnhn.fr*

Resources allocated to reproduction decrease at the range edge of an expanding population of an invasive amphibian

Predicting the magnitude and nature of changes in a species' range is becoming ever more important as an increasing number of species are faced with habitat changes, or are introduced to novel areas. An organism's investment in life history traits is expected to change during range shifts or range expansion because populations encounter new ecological conditions. We studied the reproductive investment of an invasive amphibian, *Xenopus laevis*, and tested the hypothesis that allocation to reproduction decreases at the range edge relative to the core. We measured reproductive allocation in three populations distributed from the centre to the edge of the colonized range of *X. laevis* in France. Allocation was estimated as the relative gonad mass of both sexes during the local optimal period of reproduction of the species. We observed that the relative gonad mass significantly decreased at the range edge in both sexes while body condition remained constant. Moreover, females from the range edge were sexually active later than females from the range core. The level of resources allocated to reproduction decreased progressively from the center to the periphery of the colonized range revealing changes in trade-offs between life history traits. Such a pattern could be explained by interspecific competition or enhanced investment in dispersal capacity.

P3.32 COX, RE*; CAUGHRON, JE; DAVIS, JE; Radford University; *rcox30@radford.edu*

The presence of Erysipelothrix rhusiopathiae in the mucoprotein coating of fish found in the Madre de Dios region of the Peruvian Amazon.

Erysipelothrix rhusiopathiae is the main cause of Fish Handler's Disease, a zoonotic disease that causes severe infections, joint stiffness and lymph node swelling. *E. rhusiopathiae* is found in the mucoprotein coating of fish. *E. rhusiopathiae* is contracted by humans when their skin is punctured or cut with a spine or scale of an affected fish, or if they get some of the mucoprotein coating into an already existing skin abrasion. Affected fish are asymptomatic carriers of the disease. Fish that were tested were caught in the Rio de las Piedras, several small streams feeding into the Las Piedras, and the fish markets of Puerto Maldonado, Peru. There is no literature that shows that *E. rhusiopathiae* is in this region of the world, however there is no record of it being tested for there at all. Each fish was swabbed down the ventral side, on both flanks and along the dorsal spine. Selective and differential media and staining techniques were used to confirm the presence of *E. rhusiopathiae*. Specifically, samples were grown on Triple Sugar Iron agar and tested for streptomycin resistance, catalase, and Gram stained. In total 20 fish were tested, all from various parts of the Rio de las Piedras and several tributaries. Fish tested included: *Siluriformes, Pseudoplatystoma, Piaractus brachypomus*, and several unidentified species. None of these fish tested positive for *E. rhusiopathiae*. Testing for this bacteria is important in this region of Peru, because many of the local people depend on fish as food for themselves and their families, as well as a source of income.

112.1 COX, RM*; COSTELLO, RA; CAMBER, BE; MCGLOTHLIN, JW; University of Virginia, Virginia Tech; *rmc3u@virginia.edu*

Genetic Architecture of the Anolis Dewlap Reveals Both Shared and Sex-Specific Features of a Sexually Dimorphic Ornament

In developing his theory of sexual selection, Darwin treated the ornamentation of females as a non-adaptive byproduct of sexual selection on males and the transmission of male phenotypes to females via the "laws of inheritance". Nearly a century and a half later, the extent to which the constraints of shared inheritance contribute to the expression and co-evolution of ornaments in both sexes remains largely uncertain. Here, we provide the first quantitative-genetic analysis of a sexually dimorphic ornament that has figured prominently in studies of behavioral ecology and sexual selection - the brightly colored dewlap of *Anolis* lizards. Using a paternal half-sibling breeding design in a captive population of Bahamian brown anoles (*Anolis sagrei*), we show that most aspects of this complex social signal exhibit significant additive genetic variance, including dewlap size, hue, and brightness measured from photographs and red chroma measured from reflectance spectra. Whereas sexually monomorphic components of the dewlap, such as hue, exhibit high and significant between-sex genetic correlations, sexually dimorphic components, such as size and brightness, exhibit reduced between-sex genetic correlations that do not differ from zero. From a multivariate perspective, within- and between-sex genetic variance-covariance matrices reveal a combination of shared and sex-specific features underlying the genetic architecture of the *Anolis* dewlap. We discuss these results in the broader context of genetic constraints on the evolution of sexually dimorphic phenotypes and implications for the evolution of male ornaments by various models of sexual selection and their assumptions about heritability of male ornaments.

30.2 COX, C. L,*; DAVIS RABOSKY, A. R,; WATSON, C. M.; COX, Christ; Georgia Southern University, University of Michigan, Midwestern State University; *clcox@georgiasouthern.edu*

Convergent Evolution of Decoy Coloration in Lizards

Conspicuous antipredator coloration has long fascinated biologists and provides some of the most striking examples of convergent evolution. Research has tended to focus on mimicry and aposematic coloration, which have evolved convergently in many groups and is governed by spatial and temporal heterogeneity of selection. However, decoy coloration is another type of antipredator coloration that directs predator attacks towards a brightly colored but non-lethal body segment, which may exhibit different macroevolutionary dynamics. We studied the evolution of the brightly colored (red, green, blue, or yellow) tail of many lizard species, which effectively directs predator attacks towards the autotomous tail and away from vital body parts. Using a time-calibrated phylogeny of nearly 700 species, we studied the evolutionary dynamics of decoy coloration among lizards in the clade Scincoidea. We estimated the number of origins of the blue and red tail, tested the evolutionary association of the blue tail with dorsal striping, and characterized how temporal dynamics vary among tail color type using phylogenetic comparative methods. We found that both the red and blue tail have similar numbers of evolutionary origins, and reversions to the cryptic tail color are rare. In addition, the presence of either the blue or red tail was evolutionarily correlated with dorsal striping. Finally, we found that the blue tail had both old and more recent origins, while the red tail had multiple recent origins. These results suggest that the evolution of decoy coloration can be dependent on the evolution of other phenotypic traits (dorsal striping) and highlights the dynamic and convergent evolution of decoy coloration in lizards.

18.2 CRAIG, CW*; FELDER, DL; Univ. Louisiana, Lafayette; *cwc2929@louisiana.edu*

Establishing a Global Consensus on Hermit Crab Evolution Through Molecular Phylogenetic Analysis

It is crucial to expand our understanding of marine biodiversity as evidence of a terrestrial biodiversity crisis mounts and similar challenges are imposed on marine systems. In the wake of the Deepwater Horizon oil spill in the Gulf of Mexico, surveys documenting the makeup of benthic communities noted changes in the health and diversity of decapod crustaceans at repeatedly sampled sites, suggesting that such diversity may be an important indicator of ecosystem health. Among decapods, hermit crabs may be especially sensitive to environmental fluctuations because their reliance on abandoned snail shells for shelter creates a complex dependence on a functioning ecosystem. Drawing on extensive museum collections at the National University of Singapore and the University of Louisiana, Lafayette, DNA sequences were used to infer a maximum likelihood phylogeny for the genera *Paguristes* and *Areopaguristes*. This subset of hermit crabs is known for high levels of cryptic diversity worldwide, allowing comparisons of species diversity across contrasting habitats and environmental gradients. Results presented here confirm the presence of previously unacknowledged species in the western Atlantic, and preliminary evidence suggests a similar situation in the western Pacific. Results also refute morphologically based hypotheses that both target genera are monophyletic. This discord between morphological and molecular data warrants reassessment of the phylogenetic signal in ostensibly diagnostic morphological characters, while also providing a molecularly based template for inference of evolutionary processes. Knowledge of hermit crab biology superimposed on a robust molecular phylogeny can yield testable hypotheses about the nature of hermit crab biodiversity to further inform environmental and biogeographic studies.

P3.131 CRAIN, DC*; WINFIELD, ZC; MANSOURI, F; USENKO, S; TRUMBLE, SJ; Baylor University; *dani_crain@baylor.edu*
Determining Potential Pregnancy Occurrences using Whale Earplugs
Whale earplugs are known to store lipophilic hormones and chemical information over the life of the individual. During this study we investigated changes in progesterone levels in the cerumen of five species of baleen whales (N=12) from the early 1900s to present day: fin whales (N=5), humpback whales (N=3), blue whales (N=2), minke whales (N=1), and bowhead whales (N=1). Laminae within each earplug are accreted into light and dark bands and are estimated to correspond to one year of life of the whale. After laminae were dissected from the earplug, lipids were extracted and assayed for the hormone progesterone which was used as a proxy for pregnancy occurrences. Peaks in progesterone were identified and overall relative percent change among lamina was calculated in order to estimate pregnancies. Furthermore, laminae progesterone concentrations and potential pregnancy events were compared with known sightings of female and calf. Minimum progesterone concentration detected was 0.03 ng/g and maximum was 20.8 ng/g. Inter-pregnancy intervals for all whales combined was 3.6 years, for fin whales 3.1 years, for humpback whales 4.0 years, for blue whales 4.8 years, for minke whales 4.4 years, and for bowhead whales 3.4 years. Average pregnancy rate per year for all whales was 0.22. Using whale earplugs to estimate lifetime pregnancy occurrences is a powerful tool which can be used in order to compare pregnancy rates and intervals from the early 1900s to present day to birth rates and inter-calving intervals.

132.7 CRALL, JD*; SWITZER, CM; OPPENHEIMER, RO; COMBES, SA; Harvard University, University of New Hampshire, University of California, Davis; *james.crall@gmail.com*
A Neonicotinoid Pesticide Disrupts Nest Behavior and Social Interactions in Bumblebee Colonies
Bees provide vital pollination services in both wild and agricultural ecosystems. Despite mounting evidence that neonicotinoid pesticides impair growth of bee colonies at sub-lethal levels of exposure, the mechanisms driving these effects remain unclear. While the receptors targeted by neonicotinoids are widespread within the insect central nervous system, potentially impacting a variety of key behaviors, previous work has focused largely on neonicotinoids' effects on individual bees foraging outside the nest (i.e. on learning and navigation). Here, we investigate the impacts of a common neonicotinoid pesticide (imidacloprid) on social behavior within the nests of bumblebee colonies (*Bombus impatiens*). Using an automated behavioral tracking system, we show that exposure to a single, field-realistic daily intake of imidacloprid has drastic effects on nest behavior in bumblebees: treated bees showed reduced rates of brood care and activity after treatment. Imidacloprid-treated bees also shifted occupancy patterns within the nest and had fewer social interactions with nestmates, altering the structure of the social network within colonies. Our results demonstrate that neonicotinoids impact a range of vital behaviors in bees and suggest a new avenue by which these pesticides may affect social behavior in bees, impair colony growth, and impact the health of bee populations.

84.8 CRANDELL, KE*; SUTTON, GP; BURROWS, M; FEDERLE, W; University of Cambridge, University of Bristol; *kec51@cam.ac.uk*
Jumping from Substrates of Variable Compliance and Mass in Locusts
The physical properties of a substrate affect locomotor performance. Here, we examine how locust jump velocity is affected by the stiffness (spring constant) and effective mass of the substrate by using bending beams of variable width and thickness. We used nymphal locusts (0.8 +/- 0.2 grams), which use a catapult mechanism for propulsion. Locusts jumping from substrates with a lower spring constant achieved significantly smaller take-off velocities than jumps from stiffer substrates ($F_{1,98}$=5.29, p = 0.024; velocity = 0.8 +/- 0.19 m/s on substrate of k=2.51 m/N vs. velocity = 0.73 +/- 0.17 m/s on substrate of k=0.94 m/N). Jumps from substrates with the same compliance but a larger effective mass (corresponding to 1.86 times the locusts' average body mass) resulted in significantly higher take-off velocities than jumps from lighter substrates (corresponding to 0.46 times the locusts' average body mass)($F_{1,164}$ = 9.47; p =0.0025; velocity = 0.88 +/- 0.18 m/s on heavy substrates, velocity = 0.79 +/- 0.19 m/s on light substrates). The difference in take-off velocity between heavy and light substrates was larger for smaller insects ($F_{1,164}$ = 0.64; p = 0.038). This result suggests that both the inertia and the compliance of the substrate play an important role in the resulting performance.

34.5 CRANE, RL*; KISARE, SA; PATEK, SN; Stanford Univ., Hopkins Marine Station, Duke Univ.; *rlcrane@stanford.edu*
Strategic strikes: how mantis shrimp crack open different prey
To fracture armored prey, crushing and peeling predators often strategically apply loads targeted to a prey's particular morphology. However, unlike the slow, crushing forces of many such predators, some mantis shrimp (Stomatopoda) use small, lightweight appendages to deliver ultrafast, high-impact strikes with disproportionately large peak forces relative to their body size. Yet hard-shelled prey still present a challenge for mantis shrimp - taking from several to hundreds of strikes to crack. We tested how mantis shrimp (*Neogonodactylus bredini*) adjust their striking strategy to fracture different prey. Mantis shrimp were fed snails from their native habitat that had three shapes: high-spired (*Cerithium atratum*), medium-spired (*Tectarius muricatus*) and globular (*Nerita peloronta* or *Nerita tessellata*). We video-recorded 38 mantis shrimp striking snails of each genus until they started eating (96 trials). The location and timing of every strike was recorded (strikes/trial: mean=86, range=9-460). Mantis shrimp rarely (mean 5% strikes averaged across trials) struck the middle whorls of any of the snails. They focused their strikes on the aperture of the globular (mean 81%) and medium-spired snails (mean 74%), whereas they more frequently struck the apex of high-spired snails (mean 58%). Corresponding to strike locations, the majority of mantis shrimp fractured the shell enough to feed at the aperture of globular (76%) and medium-spired snails (68%) and at the apex of high-spired snails (70%). Therefore, mantis shrimp strike different locations depending on snail morphology. Their ultrafast hammers are potent weapons that enable mantis shrimp to crack open relatively large shells, yet their behaviors suggest that these strikes must also be strategically placed depending on a shell's shape.

114.5 CRAWFORD, C. H.*; FLAMMANG, B. E.; New Jersey Institute of Technology; *crawford.callie@gmail.com*

Skeletal Morphology of a Walking Cavefish

We recently showed that the walking cavefish, *Cryptotora thamicola*, walks with a diagonal-couplets lateral sequence tetrapodal gait. While other fishes have been observed making terrestrial excursions via a number of behavioral adaptations, they do not possess morphological modifications that support tetrapodal walking. Our understanding of the evolution of terrestrial locomotion has been limited by the lack of extant archetypal organisms from which we can experimentally quantify the morphological changes that result from gravitational loading. Here we provide a detailed skeletal analysis and show that *Cryptotora* possesses morphological traits that are otherwise seen only in terrestrial vertebrates for support of body weight during locomotion. *Cryptotora* exhibits the axial and appendicular skeletal innovations characteristic of those described in tetrapods that allow tetrapodal walking. These morphological features include vertebral zygapophyses, broad neural arches, and robust pectoral and pelvic girdles fused with the vertebral column. These skeletal features strengthen the body against gravitational loading and provide for attachment of large muscles. Comparison of the skeletal morphology of *Cryptotora* with a typical fish and salamander morphology illustrates the skeletal requirements for supporting body weight outside of water. Further study of this unique fish will contribute to our understanding of the evolution of walking.

133.4 CRAWFORD, K *; KARIMI, KR; St. Mary's College of Maryland; *kcrawford@smcm.edu*

GFP Illuminates the Role of Retinoic Acid in Regenerating Axolotl Limbs

Retinoic acid (RA), a vitamin A derivative, is involved in patterning during vertebrate limb development and urodele limb regeneration. Treatment with RA during limb regeneration can proximalize, posteriorize, and ventralize blastema cell positional memory and regenerate outcome. The purpose of this study was to take advantage of the green fluorescent protein (GFP) axolotl to visualize the regional stump contributions to regenerated limbs with and without RA treatment. To accomplish this, we grafted GFP anterior or posterior zeugopodial level half limbs to white sibling hosts to create two different limb morphologies: 1) sham-like normal limbs with either anterior or posterior half GFP allografts to white hosts; or 2) half GFP half white double anterior or double posterior limbs. As controls, anterior and posterior half zeugopod limbs were surgically created. Post healing time, all limbs were amputated at the wrist level, to visualize the cellular contributions of the GFP/white limb domains during regeneration. Four days post amputation, half the animals from each group were injected with either RA (150µg/gram body weight) to induce complete proximalization of the regenerate limb pattern, or 3µl/gram body weight dimethyl sulfoxide, the carrier solvent. Limbs were monitored and photographed periodically to determine the regional contributions of both anterior and posterior limb elements to the control and RA treated limbs. After regeneration, limbs were fixed, stained, and cleared to observe regenerate limb pattern. Our results support previous observations that the anterior half limb is not only responsive to RA, but also the major contributor to RA treated proximalized regenerate limbs.

14.6 CREAGER, SB; PORTER, ME*; Florida Atlantic University; *me.porter@fau.edu*

A Comparative Study on the Tensile Properties of Shark Skin

In sharks, the skin acts as an exotendon, controlled by internal muscular pressures produced during extension and relaxation enhancing body stiffness during swimming. The surface of shark skin is covered with denticles which have drag-reducing properties thought to increase swimming speeds in some species. Dermal denticle morphology has been shown to vary regionally along the body and correlate with swimming performance across species. Our goal is to assess regional differences in denticle density and skin tensile properties in four coastal species of shark (Carcharinus limbatus, Carcharinus leucas, Sphyrna tiburo, Sphyrna lewini). We hypothesized that the denticle density and tensile strength (MPa), stiffness (MPa), and toughness of skin (Jm3) would vary regionally along the body of an individual and among species. Juveniles from each species were obtained and skin was dissected from the underlying fascia and muscle at 10 anatomical landmarks. An hourglass-shaped punch was used to extract the skin samples in a cranial to caudal orientation. Denticle density was counted using a dissecting microscope. Denticle density varied significantly among both regions and species, and showed a significant species region interaction. Skin samples were tested in tension at a strain rate of 2 mm/sec until failure on an Instron testing system using a 2kN load cell. A stress strain curve was generated for each sample and tensile properties were calculated. We found significant species and region effects for all three tensile properties. We also found a species by region interaction for stiffness.

S3.3 CRESPI, E. J.*; TRAVIS, J. A.; Washington State University, Florida State University; *erica.crespi@wsu.edu*

The search for mechanisms underlying evolutionary trade-offs in response to different selection pressures in the least killifish

Evolutionary theory predicts that natural selection acts to maximize fitness by optimizing a life history that includes trade-offs between reproduction and survival. While there is compelling evidence that selection acts in this way, we know remarkably little about the physiological and molecular mechanisms that generate and regulate these trade-offs. With more than 20 years of ecological, behavioral, and genetic data, the least killifish is an excellent model to examine the endocrine and molecular systems that mold the trade-offs we observe. Multigenerational exposure to either high conspecific density or high predation in natural populations has selected for divergent life history traits of this live-bearing fish: females from populations at historically high densities consistently are smaller in size with small clutches of large offspring, while females from low-density populations with high predation risk are larger in size, with large clutches of small offspring. We are testing the hypothesis that selection has integrated alternate physiological regulatory networks that coordinate the expression of these life history traits according to perceived changes in the environment. Our initial studies support this idea, as phenotypic and endocrine responsiveness to environmental conditions and interactions between neuroendocrine axes vary between populations that were historically exposed to either high-density or high predation risk. Future studies that combine selection experiments with functional genomic, epigenetic and endocrine analyses will resolve the complex but efficient connections within physiological and molecular networks that generate specific phenotypic trade-offs that maximize fitness in populations under different selection pressures.

BERN.1 CREWS, David; University of Texas at Austin; *crews@mail.utexas.edu*
We have soiled our next: Now what?
Our environment is now permanently contaminated. Beginning with the Industrial Revolution to the more recent Chemical Revolution, the confluence of environmental stressors has reached a point of no return. For example, endocrine disrupting chemicals (EDCs) continue to be produced and many persist in the environment. Even chemicals no longer in production (an example are polychlorinated biphenyls (PCBs), banned in the USA, Canada and Europe for decades) continue to be detectable in body tissues of virtually all wildlife (including humans). With climate change and the melting of polar ice caps, more PCBs are liberated into the environment such that the global burden is actually increasing in parts of the world. Organisms are exposed to mixtures of chemicals, often unique to particular geographies, and little is known about these effects at the level of individuals, even though population level effects are obvious. In environmental toxicology a guiding principle is that for every chemical there is a threshold level, below which there is no response. There is now clear evidence that for at least three EDCs there is no threshold. Because transitions between critical life stages (e.g., conception, birth, and adolescence) are modulated by a delicate balance of naturally occurring hormones, any EDC contamination changes endocrine signalling systems with severe consequences. We know that individuals with high body burdens of EDCs have compromised immune systems. But focusing only on EDCs is overly narrow. Organisms living around human habitation must also contend with light when it should be dark, Increasing global temperatures impose challenges to thermal adaptations (via Q10 principles). Air pollution, hypoxic aquatic conditions, and open pit mining for metals and minerals are just a few of the other permanent changes in our ecosystems. Taken together anthropogenic changes to the environment represent a rapidly accelerating evolutionary force with unpredictable outcomes.

65.3 CRICKENBERGER, S*; WETHEY, DS; University of South Carolina; *scricke@gmail.com*
Do temperature and competition interact to set a range limit?
Climate change is altering the distribution and abundance of marine organisms. Understanding the mechanisms responsible for driving these changes can be challenging due to the decade to century long time scales. The shorter time scale of range shifts due to extreme events makes them more tractable. In the 1960s the barnacle *Semibalanus balanoides* was present along the USA east coast south to Cape Hatteras, NC (35°N). Since then the southern range limit in this region has retracted poleward 350 km to Lewes, DE (38.5°N). Following the extremely cold winter of 2014/2015 recruits were present between Lewes and Cape Hatteras. We tested whether temperature limits to reproduction or temperature limits to survival prohibited colonization of *S. balanoides* within its historical range, and if the observed pattern of recolonization was dependent on stepping-stone dispersal in consecutive cold winters. Models of larval dispersal with a temperature-dependent competency window predicted dispersal was possible from currently established populations to the southern limits of recruitment observed in 2015. Successful reproduction was likely possible just north of Cape Hatteras in all years since the 1960s. All recruits in monitored quadrats throughout the region of range re-expansion died. During surveys in March 2016 adult *S. balanoides* were present at a heavily shaded site near Cape Hatteras. By July 2016 these adults were covered in *Chthamalus* recruits. Experiments are currently in progress to determine whether competition eliminates *S. balanoides* from shaded microhabitats where temperatures are not lethal. Low post-settlement survival most likely contributed to the retraction of *S. balanoides* since the 1960s. It remains to be seen if competition further constricts the range of *S. balanoides* in this region.

53.2 CRISP, LM*; LEE, DV; Univ. of Nevada, Las Vegas; *leximoore@gmail.com*
Everyone digs: Burrowing biomechanics of pocket gophers, kangaroo rats, and pocket mice
Using 3D X-ray (XMA) and our custom built Tunnel-tube, we measured burrowing kinematics and dynamics. Here we present an analysis of burrowing data collected from three closely-related, yet morphologically disparate rodent species. Botta's pocket gophers (*Thomomys bottae*) spend most of their lives foraging underground, making them an ideal test subject for studies of burrowing. Further, pocket gophers are closely related to kangaroo rats (*Dipodomys merriami*) and pocket mice (*Chaetodipus penicillatus*), all of which fall within the superfamily Geomyoidea. These rodent species each dig their own burrows, yet have very different body types and body sizes (from 20g to 200g). Pocket gophers have short limbs, long claws, and a compact body, whereas kangaroo rats have long hindlimbs and short forelimbs for bipedal hopping. Pocket mice have a generalist rodent body plan with crouched posture and hindlimbs slightly longer than forelimbs. All three species burrowed through the Tunnel-tube in two substrate conditions: a soft radiolucent substrate and soft natural soil. In both substrates, all species exhibited scratch-digging, using the forelimbs to loosen and remove the substrate. In the radiolucent substrate, digging force was lowest for pocket mice, yet kangaroo rats and pocket gophers produced nearly identical forces. However, in natural soil, digging force scaled as expected with body weight. These findings suggest that the low compressive strength of the radiolucent substrate may limit digging force in this substrate. Furthermore, we found that for digging force, body weight scaled to 0.63. We would expect a similar finding for muscle cross-sectional area (XSA), where body weight$^{0.66}$. This contrasts with force during terrestrial locomotion, where force is directly proportional to body weight because limb posture compensates for muscle XSA. Thus, we suspect that digging force is limited by muscle XSA.

69.8 CRISWELL, KE*; COATES, MI; GILLIS, JA; University of Chicago, University of Cambridge; *kcriswell@uchicago.edu*
The evolutionary and embryonic origins of the gnathostome vertebral skeleton
Vertebral anatomy and development vary across jawed vertebrates (gnathostomes). Centra, in particular, have originated independently in numerous gnathostome clades, with distinct morphologies and tissues arising in different taxa. There is evidence that the embryonic origins of the vertebral skeleton may be distinct in different gnathostome groups. All vertebral elements in tetrapods derive from sclerotome (skeletogenic cells of the ventral portions of the somites), while teleost vertebrae are more variable, with layers of bone in the centra apparently deposited by the notochord. To test whether a notochordal contribution to centra is unique to teleosts, or whether it is a more general gnathostome characteristic, data from the sister group of bony fishes, the chondrichthyans, are needed. Here we determine the embryonic origin of the vertebral skeleton in the little skate, *Leucoraja erinacea*, using somite and notochord fate mapping experiments. CM-DiI injected into ventral somites was traced to the neural and hemal arches, as well as the inner and outer layers of the centrum. Also, a layer of spindle-shaped cells surrounding the notochord, which has been posited as a derivative of the notochord epithelium in elasmobranchs, was discovered to be somite-derived. Complementary long-term notochord fate mapping experiments show that notochord cells do not contribute to any vertebral elements in the skate. These experiments demonstrate that a sclerotomal origin of the vertebral skeleton is a general feature of gnathostomes, and that the teleost condition, in which the notochord contributes to the centrum, is probably a specialized exception. Significantly, tetrapods and elasmobranchs employ the same tissues to build centra, despite having evolved these structures independently.

93.3 CROCKER-BUTA, SP*; LEARY, CJ; Univ. of Mississippi;
scrocker@go.olemiss.edu
Bidirectionality of Hormone-Behavior Relationships and Satellite-Caller Dynamics in Male Green Treefrogs: Multiple Factors Mediate Mating Tactic Expression

Whether hormonal differences among males that conditionally alternate between mating tactics are a cause or consequence of behavioral expression is central to understanding the mechanisms regulating the adoption of a particular tactic. This issue is pertinent to alternative mating tactics in anurans because the social-acoustic environment can mediate changes in both tactic expression and hormone levels. Hence, it is not clear whether males adopt different tactics in response to rival male signals, hormone levels, or both. Here we address this problem in male green treefrogs, *Hyla cinerea*, using vocal playback experiments combined with measurement of circulating hormone levels, call attributes, body size and body condition. Despite our previous work showing that individual differences in corticosterone (CORT) and androgen levels can arise during social interactions and are casually related to tactic expression in this species, playback experiments revealed that hormone levels did not predict whether a male adopted non-calling satellite behavior or continued to call in response to broadcast advertisement calls. Rather, smaller males in poorer body condition that produced shorter duration calls were more likely to adopt satellite behavior in response to the broadcast stimulus. Collectively, our results illustrate that several approaches should be taken to address the potential bidirectionality of hormone-behavior relationships because multiple factors can influence mating tactic expression.

P3.220 CROCKETT, ME*; BERGMANN, PJ; Clark University;
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Running on uneven surfaces: The effect of substrate particle size and unevenness on performance

The physical characteristics of substrates that terrestrial animals move on can affect their locomotor performance and kinematics. Uneven surfaces are ubiquitous in nature and animals must frequently move across them, yet their effects on locomotion are not thoroughly understood. We studied how particle size and surface irregularity of uneven substrates made of large particles affect the locomotor performance and kinematics of the terrestrial generalist sprinter, the Northern Curly Tailed Lizard (*Leiocephalus carinatus*). To look for differences in locomotor performance, we compared seven substrates: a flat surface, three sizes of spherical balls ranging from 43 to 113 cm in diameter, and three sizes of natural rocks matched to the ball sizes. The flat substrate provided an even surface and served as the control, spherical balls provided a regular but uneven surface, and natural rock substrates provided an irregular and uneven running surface. As the size of the particles increases, the unevenness of the surface increases, which poses a challenge to animals running upon it. We expected that as unevenness increased, sprint performance would decrease. We also expected that as irregularity increased, sprint performance would further decrease because lizards would need to constantly adjust their stride while running, compared to the regular substrates. This work helps us understand how substrate unevenness and irregularity affects locomotor performance, which will have implications on microhabitat selection in nature, and how animals compensate for such challenges during locomotion.

126.2 CROFTS, S B*; FLAMMANG, B E; NJIT; *crofts@njit.edu*
Functional morphology of marine reptile caudal fins

Multiple independent land-to-sea transitions in extinct reptiles led to a great diversity of secondarily marine reptiles during the Mesozoic. Ichthyosaurs, as well as members of the mosasauridae and thalattosuchian crocodylomorphs, relied on axial undulation and converged on a bi-lobate caudal fin morphology. While these tails are superficially similar to shark caudal fins, the vertebral column supported the ventral lobe of the tail. It has been proposed that this may have been to counteract the buoyancy of the reptiles' lungs or may have helped make the animals more manoeuvrable when diving. Coupled with the question of tail morphology are changes in body and tail flexibility. It has been hypothesized that as these lineages adapted to more obligate marine lifestyles there was an increase in overall body stiffness, which would have led to more efficient locomotion. In ichthyosaurs, body stiffness has been estimated based on vertebral morphology, but this does not address stiffness conferred by soft tissues or muscle activation, and this only addresses the stiffness of the ventral lobe. Our goal is to understand how skeletal and soft tissues affect tail stiffness in both lobes and how this relates to fluid dynamics. Using sharks as an extant analogue, as well as 3D printed models, we are comparing tail flexibility and morphology to better understand the natural history of these long extinct marine reptiles. Shark tail flexibility varies between species, as do skeletal and soft tissue morphologies, but for all species the dorsal lobes are more passively flexible than the unsupported ventral lobes. Understanding the relationship between tail morphology, stiffness, and fluid dynamics will help us better explain the convergent evolution of extinct marine reptile tails and their function.

P3.205 CROGHAN, J; Ohio University;
jasmine.croghan@gmail.com
Diet and the Cryptodiran Skull: A 3D Morphometric Analysis

Diversity in testudine cranial shape is hypothesized to reflect aspects of ecology and behavior. To investigate the functional links between feeding behavior and the morphology of the Cryptodiran skull, I performed a landmark-based 3D geometric morphometric analysis of cranial form in 12 species representing the phylogenetic and behavioral breadth of the clade. Virtual 3D models were produced from CT scans, and landmark data were collected using the auto3dgm package in the program R. Published data using bulk measures of diet were restructured into proportional categories reflecting an estimate of food-jaw contact and the material properties of food items. Shape data and diet were compared using two-block partial least squares analysis in GeomorphR, which returned a high correlation between the datasets ($r=0.85$), but was non-significant ($p=0.09$). A greater proportion of tough vegetative matter is associated with dorsoventral compression of the caudal skull; trochlear and articular surfaces that are perpendicular to the long axis of the skull; a vertically oriented anterior adductor chamber that alters the orientation of the adductor mandibulae externus tendon; and a concave labial margin. In contrast, hard animal matter is associated with a caudal skull that increases in height caudally; a more caudally inclined anterior adductor chamber; a laterally oriented trochlear and articular surface; a smoothly convex labial margin; and a more pointed and elongate squamosal eminence. This analysis has uncovered sources of variation in anatomical details that may vary predictably with diet beyond the external head dimensions discovered in previous analyses.

S11.10 CRONIN, T.W.*; LIN, C.; UMBC; *cronin@umbc.edu*
Crustacean larvae - vision in the plankton
Marine crustaceans frequently experience a complex life history. In most species, a series of distinct planktonic larval stages metamorphoses into an adult that may continue to be planktonic (e.g. copepods, euphausiids) or switch to an adult lifestyle varying from nektonic (e.g. decapod shrimp, some crabs) to benthic (e.g. most crabs, lobsters, stomatopods) or even sessile (e.g. barnacles). The photosensitive organs of these larvae range from simple naupliar eyes, with one or a few optical elements, to rather complex (if tiny) compound eyes consisting of several to dozens of ommatidia (at which point they perhaps leave the realm of "low-resolution eyes"). Larval eyes often have special adaptations to reduce their visibility in natural waters, some of which are optically novel. At the time of metamorphosis, the optical system of larval compound eyes changes from the characteristic transparent apposition type to an early adult eye of a different type, most often to a standard apposition eye or a type of superposition eye. This can occur by enlargement and rather simple remodeling or can require the replacement of the larval eye with a completely new adult retina and optical system (as in stomatopods). Crustacean larval eyes contribute to many simple photobehaviors which vary with the particular environment in which the larva finds itself. Many crustacean larvae are highly competent predators, and their eyes likely foster a genuine visual sense for detection, identification, and localization of prey (and possibly predators as well). Larval visual ecology and the neurobiology of larval crustacean vision continue to be areas of active research.

20.5 CROVO, JA*; JOHNSTON, CE; Auburn University, Auburn University ; *jac0058@auburn.edu*
Rhapsody in Reproduction: Acoustic Modulation of Gonadal Hormones in a Cyprinid Fish
Acoustic signaling is a vital component of courtship and agonistic behaviors. In fishes, acoustic signals advertise important characteristics, such as mate quality and sexual receptivity. These signals also have the capacity to modulate the endocrine response of the target individual. We used the Blacktail Shiner (*Cyprinella venusta*), a soniferous cyprinid, as a model to investigate the acoustic modulation of gonadal hormones. Male and female *C. venusta* were exposed to two conspecific call types: growls and knocks. We used enzyme-linked immunosorbent assay (ELISA) to measure changes in waterborne levels of estradiol, testosterone, and 11-ketotestosterone (11KT) during exposure to acoustic signals. Males exposed to knocks exhibited a significant elevation in 11-ketotestosterone and testosterone; knocks are frequently produced during aggressive interactions. Females exhibited a significant decrease in estradiol after exposure to growls; a signal produced during courtship - suggesting that acoustic cues facilitate spawning by synchronizing gamete release. Future work aims to investigate the modulation of hormone levels while presenting an acoustic and visual cue simultaneously.

57.6 CROWE-RIDDELL, JM*; LILLYWHITE, HB; PARTRIDGE, JC; SANDERS, KL; Univ. of Florida, Gainesville, Univ. of Western Australia, Perth, Univ. of Adelaide; *jenna.crowe-riddell@adelaide.edu.au*
Tail photoreception: investigating a novel sensory system in Australian sea snakes
Studies of non-visual phototaxis provide excellent opportunities in integrative biology, but few examples are known in tetrapods. The photoreceptive tail of the olive sea snake (*Aipysurus laevis*) was first reported by night divers: sheltering snakes retract their vulnerable tail paddles in response to torch light. Our research aims to understand the evolutionary origins, genetic basis and ecological significance of this remarkable trait. We will present results of behavioural experiements showing that tail photoreception is not restricted to *A. laevis* but likely evolved only within the *Aipysurus* clade. Gene expression analyses from skin transcriptomes reveal candidate visual genes and pathyways involved in tail skin photoreception. Finally, we will report on preliminary investigations of the ecological significance of this rare case of non-visual phototaxis in vertebrates.

P2.178 CROWLEY-GALL, A*; ROLLMANN, SM; Univ. of Cincinnati; *a.crowleygall@gmail.com*
Effects of Host Availability on Peripheral Olfactory Perception in Drosophila mojavensis
Geographic variation examines phenotypic variation as a result of environmental changes along a geographic gradient. Host availability across a geographic range can affect host plant preference in herbivorous insects that rely on plants for feeding and breeding. The cactophillic fly *Drosophila mojavensis* is an interesting model in which to study geographic variation, as it is comprised of four geographically isolated populations. Each population specializes on a different host cactus despite the host cacti at times having overlapping ranges and uses the distinct odorants emitted by the cactus to identify their appropriate host plant. Here, we examine the effect of host availability on the peripheral olfactory system within and between *D. mojavensis* populations. We measured electrophysiological responses of odorant receptor neurons to single cactus volatiles and show intrapopulation differences in specificity and sensitivity of olfactory receptor neurons to cactus volatiles. This suggests that the peripheral nervous system has changed in response to host availability and these changes could play a role in differentiating between host cactus species.

P1.70 CRUZ, M/A*; HAMMERMAN, N/M; LUCAS, M/Q; WEIL, E; SCHIZAS, N/V; Univ. of Puerto Rico, Interamericana Uni. of Puerto Rico ; *mariel.cruzramos@gmail.com*

Population structure of the octocoral predator, Cyphoma gibbosum, in the wider Caribbean

The predatory snail *Cyphoma gibbosum* has significant ecological impact on the octocoral community under outbreak conditions. A study done off La Parguera, Puerto Rico, found that *C. gibbosum* was a significant predator of the octocoral communities. Overfishing has removed most snail predators and there is concern over population outbreaks of corallivorous invertebrates such as *Cyphoma* resulting in increased predation to octocoral and coral colonies, loss of reproductive tissue, and a source of vectoring diseases. There is no data on the genetic population structure of gastropod *Cyphoma gibbossum*; it is an ideal species to use for genetic analysis to infer patterns of population structure given its ecological importance in the octocoral community. We collected 62 *C. gibbosum* samples from 6 locations in the Caribbean: Mona Island, La Parguera, Enrique Reef, Culebra, Dominican Republic, and Curaçao and are currently sequencing mitochondrial cytochrome C Oxidase subunit I (COI) and nuclear markers, calmodulin (CAL) and cyclophilin A (CYCA) to examine the genetic diversity and population genetic structure of *Cyphoma gibbosum*.

P1.72 CRUZ, P*; FOLKS, N; ANDERSON, S; TRAVIS, D; GONZALEZ, VH; HRANITZ, JM; BARTHELL, JF; Montclair State University, University of Texas at El Paso, University of Kansas, Boston University , University of Kansas, Bloomsburg University, University of Central Oklahoma; *cruzp3@montclair.edu*

Attractiveness Of The Dark Central Floret In Wild Carrots In Western Turkey

The wild carrot, Daucus carota, naturally occurs in Europe, Asia and North Africa, and it has been introduced in North America, Australia, New Zealand, and South Africa. The function of a dark central floret has been debated for many years. It has been suggested that it is a vestigial structure without a function, that it serves as a long or short distance signal to attract pollinators, or that it might function as a defense mechanism against herbivores. We experimentally tested the attraction of pollinators to umbels with the dark floret in D. carota in western Turkey (Canakkale). We recorded the number of insect visits to umbels with a dark central floret and umbels in which the dark central floret was removed. We also studied the effect of umbel diameter and height above ground on the attraction of pollinators to umbels with and without floret. All observations were conducted between 10:00 h and 14:00 h when insect visitation was high. The number of insect visits between umbels with and without a dark central floret were similar when they were of average diameter (10 cm) and were placed at the average inflorescence height (120 cm) of the studied population. Similarly, we did not find differences in the number of insect visits before and after the dark central floret was removed from an umbel or between umbel of small and large diameters. However, average diameter umbels with a dark central floret received more insect visits than those without it when they were placed at 81 cm above ground; no differences were observed for those umbels located at a higher height (147 cm). These results suggest that height might be a factor that influences the attractiveness of the dark central floret in the population studied.

76.5 CRUZ-NETO, AP*; CABRERA-MARTINEZ, LV; OTALORA-ARDILA, A; FLORES-MARTINEZ, JJ; HERRERA M, LG; WELCH JR, KC; State University of Sao Paulo, Rio Claro, Brazil, State Univeriwty of Sao Paulo, Rio Claro, Brazil, Universidade Nacional Autonoma de Mexico, Mexico, versidade Nacional Autonoma de Mexico, Mexico, University of Toronto Scarborough, Canada; *ariovaldopcruz@gmail.com*

The Energetic Costs Associated with Acute Phase Response in Bats

The energetic costs associated with acute phase response (APR), an integral component of the innate immune system, are thought to be high. Life-history theory predicts a trade-off between these costs and the energy invested in other life-history traits as well as an association with the slow-fast continuum of life-history strategies. Here we examine the energetic costs associated with APR in bats. Bats have a slow life-history pattern and co-evolved with lethal pathogens without any impact on their fitness. We expect that APR would be present in bats, but its costs would be lower than for fast-living rodents and slow-living birds. To test this hypothesis we measured the metabolic rate (MR) and body mass change of 3 species of Neotropical bats after challenging their immune system with lipopolysaccharide (LPS). For two of these species we also measured body temperature (Tb). APR was presented in bats as they increased MR and Tb and lost body mass after LPS administration. Mass-corrected MR of bats after LPS increased by the same amount as observed in rodents and birds. The total energetic costs associated with APR represents 1 to 8% of their total energy budgets. APR is present in bats and, like in most birds and rodents, its entail an increase in MR. However, the energetic costs associated with this response seems not to jeopardize their energy budgets. Thus it seems that differences in the life history continuum per se cannot explain differences in the costs of APR between bats, rodents and birds.

30.4 CULUMBER, ZW*; GIFFORD, ME; TOBLER, M; Kansas State University, University of Central Arkansas; *zculumber@ksu.edu*

Diversification on the macroevolutionary adaptive landscape following the loss of lungs in caudate amphibians

Evolutionary innovations frequently promote diversification by allowing access to ecological opportunity but also often result in performance trade-offs. Adaptive simplification — the secondary loss or reduction of these innovations — can alleviate functional constraints, but evidence that this process can stimulate new adaptive radiation is lacking. Using phylogenetic comparative methods across a phylogeny of 500 caudate amphibians we show that the loss of lungs in plethodontid salamanders (Caudata: Plethodontidae) was associated with an increased rate of species diversification. Adaptive simplification of the lung appears to have led to reduced energetic constraints as more than half of the mitochondrial genome — encoding proteins critical for oxidative phosphorylation — exhibited significantly relaxed selection compared to species with lungs. The macroevolutionary adaptive landscape exhibited a complex pattern of evolution. Analysis of the climatic niche indicated more adaptive peaks in lungless salamanders and that most peaks were unique to the lungless group. Overall the results are consistent with previous studies suggesting some degree of niche conservatism in temperate lungless lineages, but increased divergence in tropical lineages. However, a macroevolutionary perspective of diversification indicates that the loss of lungs is associated with increased rates of ecological diversification as expected of an adaptive radiation. The loss of key evolutionary innovations may therefore be an underappreciated mechanism of species and functional diversification.

P3.21 CUMMINGS, CR*; KHAN, NY; MURRAY, M; ELLISON, T; WELSCH, CN; HERNANDEZ, SM; NAVARA, KJ; University of Georgia; *cummings.carolineruth@gmail.com*

Influences of Urban Life and Anthropogenic Feeding on Stress and Immunity in White Ibises

Exposure to urban environments can have dramatic impacts on the health and physiology of animals, however some species are still abundant and perhaps even thrive in urban environments. White ibises are good examples of this phenomenon. While they originate in and breed in remote wetland habitats, they can be found foraging in urban parks throughout Palm Beach County, FL. Further, they readily consume human food either as a result of anthropogenic feeding or from foraging in human-generated landfills. The impacts of this exposure to urban environments and anthropogenic food sources on their health, physiology, and their potential as vectors of zoonotic disease remains unknown. We hypothesized that ibises captured in urban environments would exhibit higher levels of stress (as indicated by circulating corticosterone concentrations and heterophil:lymphocyte ratios) and would show inhibited immunity (as measured by an assay of bacteriocidal activity). To test this, we captured white ibises in both natural wetland habitats and urban environments in Palm Beach County, FL. Urban sites included 5 parks, a drive-through safari, and a landfill. Immediately after capture, blood samples were collected for later assessment of circulating corticosterone concentrations and bacteriocidal ability. In addition, we collected samples in both spring and fall to examine potential seasonal differences in these parameters. Contrary to our predictions, blood collected from ibises living in urban sites showed significantly greater ability to kill E. coli compared with ibises in urban sites, and this pattern was similar among seasons. Additionally, among urban sites, bacteriocidal ability varied significantly among sites, which may reflect degree of human contact. The significance of these results and their relationship to plasma corticosterone concentrations will be discussed.

P2.271 CUPP, JR., P. V.; Eastern Kentucky University; *paul.cupp@eku.edu*

Postural Adjustments Influence Water Balance in Green Salamanders, Aneides aeneus

Green salamanders, *Aneides aeneus*, are known to occur in crevices of rock cliffs that are humid but not wet. Postural adjustments and a high tolerance to desiccation or critical activity point (CAP) allow *A. aeneus* to respond to changes in moisture conditions that may arise in home crevices or transcient crevices. A high CAP of 36.7% found in *A. aeneus* from southeastern KY combined with inherent behavioral adjustments such as coiling of the body, aligning the tail along the body and flattening the body to the substrate all reduce body surface exposure and slow the dehydration rate and extend the time to reach CAP. During drought or dry conditions, *A. aeneus* may remain in home crevices longer and forage from crevices for short periods. A high CAP may allow them to tolerate some loss of body water (8-12%) which may be rehydrated as humidity levels rise overnight and some water condenses on rock cliffs. Also, conditions of extended rainfall resulting in water standing in crevices may subject some *A. aeneus* to over-hydration. In ten instances (equally divided in lab and field), individual salamanders were observed in postures where the limbs were raised high and the head and tail were raised off the substrate thereby significantly reducing exposure of the skin to wet substrates. One salamander shifted to an alternate posture in which all four feet were in contact with the substrate with limbs extended, and the mid-body arched above the substrate. Slight changes in posture may provide for fine control of dehydration or rehydration rates to optimize body water economy or content. Postural adjustments may allow terrestrial salamanders, such as *A. aeneus*, to remain in home crevices thereby reducing exposure to predation.

P1.113 CURLIS, JD*; HOLMES, IA; DAVIS RABOSKY, A; COX, CL; Georgia Southern University, University of Michigan; *jc12430@georgiasouthern.edu*

Spatial Variation of Mimetic and Non-Mimetic Color Polymorphism in the Western Ground Snake

Color polymorphism (when two or more discrete color types co-occur in a population) is prevalent in nature and present among various types of traits for different species. These different traits can be subjected to alternate types of selection and can exhibit variable evolutionary dynamics. Because a single species often exhibits only a single trait type, disentangling the role of organism-specific and more general evolutionary forces in driving color polymorphism can be challenging. We leveraged the coral-snake-mimicking western ground snake, *Sonora semiannulata*, which has both mimetic and non-mimetic polymorphic traits, to test whether these two types of traits exhibit different patterns of spatial variation. Using 308 specimens from 30 populations spanning the geographic range of this species, we scored each individual based on the presence or absence of 1) a red dorsal stripe or black crossbands (mimetic traits) and 2) a black cap or black nuchal band (non-mimetic traits). Both mimetic and non-mimetic traits varied widely across the landscape, with some populations exhibiting all possible morphs and others exhibiting only one. We found that mimetic trait diversity was positively correlated with non-mimetic trait diversity among populations, both when analyzed using Shannon's diversity indices (p=0.05; R^2=0.51) and when using number of morphs (although not significant, p=0.07; R^2=0.23). These findings reveal similar spatial patterns of color diversity in both mimetic and non-mimetic traits. More broadly, our results suggest that polymorphism in mimetic and non-mimetic traits is evolutionarily linked in ground snakes, with either similar selection among populations or genetic linkage between these two types of traits.

P3.191 CURRY, JE*; NAVARA, KJ; University of Georgia; *jcurry@uga.edu*

Examining natural variation in offspring sex ratios produced by Japanese quail, Cortunix japonica

It has been shown at both the population and individual levels that birds skew the sex ratios of offspring from the expected 1:1 ratio of males:females. When sex ratios are examined at the individual level, they are generally compared among two or more groups experiencing different environmental, social, or hormonal pressures. Variation among individuals that is not explained by the pressure is often labeled as just that - variation. However, what if there is more to the differences in sex ratios produced among individual birds over long periods of time? There is evidence in humans that a genetic factor may explain couples that produce long strings of boys or girls. We hypothesized that birds may also have a genetic mechanism that underlies variation in sex ratios produced by individual females. We are testing this hypothesis in three steps using Japanese quail. First, we followed a population (n = 154) of pair-housed quail and collected fertilized eggs from each pair for two weeks. We incubated the eggs for 14 days and sexed the embryos via dissection for initial findings of if there is significant variation in the sex ratios produced by individual female quail. We determined that some quail do produce strings of offspring that are of the same sex. So, the next step was to collect eggs from each of those females for 30d and use molecular mechanisms to sex them at the blastocyst stage to determine whether sex ratios are skewed prior to fertilization or via sex-specific embryonic death. The results of these two steps will be presented and discussed. The third step to be completed next is to determine heritability of sex ratio variation. The identification of a genetic mechanism underlying variation in sex ratios could further guide our understanding of how birds adjust sex ratios in the wild.

141.5 CURTIS, MD*; TURNER, RL; Florida Institute of Technology, Melbourne; *curtismi@uab.edu*

Ciliary Urns: Development and Morphology in Synaptula hydriformis

Ciliary urns are cornucopia-shaped coelomic organs known in no other sea cucumbers (holothuroids) except those of the suborder Synaptina (order Apoda). The excretory ability of urns implicates their having a role in holothuroid immune response. Although ciliary urns are widely reported in the literature, the process and histology of urn development has not yet been described. Various forms of microscopy were used to examine the development and structure of urns of the viviparous holothuroid *Synaptula hydriformis*. Mature urns occurred rarely in 10-tentacled young and commonly in later growth stages, and developing urns were found in post-pentactulae, 10-tentacled young, and released juveniles. Urns developed as rounded protrusions of ciliated collar cells on the mesenteries. The cells increased in number to become pseudostratified with a shallow lumen, forming the cushion stage (5-15 µm diameter). The subsequent spoon shaped stage (15-25 µm width) had a short stalk, deepened lumen, and extensive ciliary field. Mature urns (24.5 µm body width, 9.5 µm stalk height, 29.7 µm body height) had a thin stalk and funnel shaped body with an abluminal epithelium of squamous cells and an adluminal epithelium of densely packed pseudostratified, columnar, ciliated collar cells lining the deep lumen. Urns resembling the cushion stage in *S. hydriformis* have been described in the sea star *Archaster typicus*. Considering the basal phylogenetic position of synaptines among holothuroids and the presence of cushion urns in *A. typicus*, ultrastructural and histological examination of other echinoderm groups should reveal if cushion urns have been overlooked and are a plesiomorphy of the phylum.

123.4 CURTIS CHOITZ, C*; MICHAEL MINICOZZI, ; ALICE GIBB, ; Northern Arizona University; *cc994@nau.edu*

Do Amphibious Fishes Jump Farther Than Fully Aquatic Fishes?

Although most fishes are considered to be fully aquatic, many are able to move effectively on land using a behavior called a tail-flip jump. The tail-flip jump is also used by amphibious fishes that have modified their respiratory and integumentary systems for prolonged (days to months) terrestrial excursions. We filmed four species of Cyprinodontiform fishes performing the tail-flip jump in high speed (600Hz): three aquatic species (*Jordanella floridae*, *Gambusia affinis*, and *Poecilia mexicana*), and one amphibious species, *Kryptolebias marmoratus*. We predicted that amphibious *Kryptolebias* would produce longer jumps than the three aquatic species studied here, and that jump performance would not decline as *Kryptolebias* individuals grow larger. We also quantified the scaling relationships between body size and jump performance in both aquatic and amphibious species. As aquatic species become larger, tail-flip jump distance declines (mass scaling coefficient, m = -.22). In contrast, as amphibious species become larger, tail-flip jump distance increases (m = +.41). As *Kryptolebias* indviduals become larger, their acceleration during the preparatory phase of the tail-flip jump increases (m = +.38) and their contact time remains relatively constant (m = ~0), which allows them to reach greater take off velocities at larger body sizes. Because *Kryptolebias* has no dramatic morphological specializations for life in the terrestrial realm, we hypothesize that fish retain jump performance at relatively large sizes through evolutionary changes to axial muscle distribution and/or changes in axial muscle fiber type.

56.1 CUSSEN, VA*; CORNELIUS, JM; HAHN, TP; Univ. of California, Davis, Eastern Michigan University; *vacussen@ucdavis.edu*

Using Stable Isotopes to Elucidate Habitat Use and Movement Magnitude of Nomadic Passerines.

Understanding the movement patterns of vagile species is critical to answering evolutionary, conservation and mechanistic questions. Tracking technology has improved knowledge of animal movements, but is still limited in its applicability. Stable hydrogen isotope (δ2H) signatures in feathers are increasingly used to determine the movement patterns of bird migrations and irruptions. We used the stable isotope approach to investigate the relative movement patterns of different vocal types of red crossbill (Loxia curvirostra) in western North America. We collected ‘worn' feathers in late summer from crossbills of three vocal types: Type 5 (Wyoming), Type 3 (Washington), and Type 2 (Oregon). Worn feathers, grown the previous year, can be used to examine variation in habitat use during molt one-year prior; the inter-individual variation in worn feather isotope signatures should correlate positively with the diversity of habitat types used by the different crossbill types. Feather samples were analyzed at the UC Davis Stable Isotope Facility. We found significant between-type variation in inter-individual variability in feather δ2H (Kruskal-Wallis chi-squared=8.5, p=0.014). The isotope signature variation was larger in feathers collected from Type 2 crossbills (δVSMOW range of 65.2 units) compared to both Type 5 (δVSMOW unit range of 49.8 units) and Type 3 crossbills (δVSMOW unit range of 19.6 units). This is consistent with the different individual Type 2 crossbills having molted the previous year in a greater diversity of locations or habitats than the Type 5 or Type 3 birds. These results are consistent with the interpretation that nomadic crossbill types may differ in their degree of nomadism, and these differences in movement may be related to habitat selection and diet choice.

P3.104 CYCHOWSKI, MP*; SCHRADIN, C; HAYES, LD; Univ. of Tennessee at Chattanooga, Institut Pluridisciplinaire Hubert Curien, Strasbourg, France; *gmr586@mocs.utc.edu*

Sociality in Marine Mammals: A Re-evaluation of What Is Happening Beneath the Surface

Animal social organization (size, composition of groups) plays an important role in social interactions that affect the fitness of individuals. Most studies report a single type of social organization for each species. This is problematic because intraspecific variation in social organization has been documented in mammals. Using Web of Science, we conducted primary literature searches to determine intraspecific variation in social organization of whales (Cetaceans) and dolphins (Pinnipedia). Intraspecific variation within and between populations of whales (n=19/23) and dolphins (n=31/33) is the norm. In whales, intraspecific variation in social organization includes singletons and groups of varying size (2 to 100s); composition is rarely reported. In dolphins, social organization is more often reported and intraspecific variation includes singletons (n= 24/33), single-sexed groups (both male and female; n= 31/33), and mixed-sexed groups (n= 30/33). Fission-fusion societies (size, composition of social groups frequently change) are reported in three dolphin species. In both whales and dolphins, group size varies with different behavioral strategies (e.g. migration, feeding). These results suggest intraspecific variation in marine mammal social organization is an important part of their biology. A phylogenetic study of marine mammal social organization is critical to a comprehensive understanding of the evolution of intraspecific variation in marine mammals.

73.5 CYPHER, A.D. *; BAGATTO, B. P. ; The University of Akron; *adc51@zips.uakron.edu*

The hypoxic response is altered by the presence of endocrine disruptors and oil spill contaminants in Danio rerio.

The hypoxic response consists of many genetic, metabolic, and cardiovascular changes that interact to balance oxygen supply and demand in order to increase survival. In *Danio rerio,* this response consists of changes in parameters like stroke volume, heart rate, red blood cell (RBC) velocity, hematocrit, and metabolic rate. Anthropogenic stressors like pollutants can interact with these parameters and thus affect how the cardiovascular system responds to hypoxia. The endocrine disruptor, bisphenol A (BPA), and the oil spill contaminant, phenanthrene, a polycyclic aromatic hydrocarbon (PAH) were used in co-exposure experiments with hypoxia in eggs and larvae. Cardiovascular parameters were measured using video microscopy and digital motion analysis. We found that bisphenol A had little effect on cardiovascular parameters when exposed singly, but when in combination with hypoxia resulted in large decreases in heart rate and cardiac output in addition to RBC velocity. Exposure to phenanthrene singly resulted in decreases in stroke volume, heart rate, and RBC velocity. These decreases were exacerbated when co-exposed with hypoxia. In addition, yolk size was smaller with single exposure to phenanthrene but it was larger in co-exposed embryos indicating that phenanthrene and hypoxia exposure have opposing effects on yolk consumption and possibly metabolic rate. The effect size was also influenced by the age of the larvae indicating that the developmental stage of the cardiovascular system at exposure plays a role. Both bisphenol A and phenanthrene exposure resulted in higher mortality rates when in combination with hypoxia. This research supports the hypothesis that pollutants can affect how aquatic organisms respond and survive during hypoxic events.

P2.36 D'AMELIO, BP*; GAHR, M; ADREANI, N; TROST, L; KLUMB, M; TER MAAT, A; Max Planck Institute for Ornithology; *pietro.damelio@hotmail.it*

From Auditory Recognition to Motivation, a Journey into Unlearned Vocalizations of Zebra Finches

The study of bird vocal communication has historically focused on songs, whereas the study of unlearned calls has not been given much attention. Songs are elaborated and long whereas calls are much shorter and simpler; but while the first only serve few functions the latter are employed in a myriad of situations. Calls are used from alarming to recruit feeding companions and, most interestingly, calls can mediate social relationships. To fully investigate these functions of the unlearned calls in the zebra finch we took advantage of a device to record the daily vocalizations of each bird individually. We developed and used miniaturized backpack microphones (0.6 grams) and, in combinations with standard experimental approaches and neurobiological technics, we addressed 3 questions. 1) How does the vocal communication develop within a pair of birds? 2) Are the unlearned calls individually recognized? 3) Is the telencephalic motor vocal pathway, which controls learned vocalizations, also involved in the production of calls? We discovered that mates established precise patterns of alternated calling during pair formations. We also found that the calls used with precise tempo are individually recognized. Moreover, studying the neural control of these unlearned vocalizations, we found that lesions of the telencephalic nuclei influenced the spectral features of these unlearned vocalizations whereas they do not influence their temporal pattern (i.e. duetting with the partner). In conclusion, we characterized the calling system of a Passeriform at multiple mechanistic levels, from motor control to call motivation. We aim to show the potential influence of our findings for different fields, from comparative studies between vocal learners and non-learners to pair formation and compatibility.

P2.85 DAAB, C; SMITH, A; SHYAMAL, S*; DURICA, DS; Univ of Oklahoma, OK; *ddurica@ou.edu*

Vitellogenesis and Limb Regeneration over the Molt Cycle in the Cherry Shrimp, Neocardinia deticulata, a proposed Crustacean Transgenic Model

The cherry shrimp, *Neocaridina denticulata*, has been proposed as a transgenic model organism for Crustacea[1,2]. As a pet species, it is inexpensive, and can be cultured in fresh water aquaria. It has a life cycle amenable to genetic manipulation; eggs are fertilized upon laying and are kept on the 'berried' female pleopods until hatching. Embryos directly develop into juveniles with no planktonic larval stage, reaching reproductive maturity in 4-6 months. We have established several cultures of cherry shrimp color morphs. Although animals are tolerant to poor water quality and remain viable, in our hands, egg development seems be impeded at high pH or nitrate/nitrite levels; oogenesis will initiate, but completion of vitellogenesis is impaired. Limb regeneration is uncoupled from the molt cycle and multiple limb autotomy will not accelerate molting. Limb development is also not coordinately regulated relative to molt and presumed circulating ecdysteroid titers, since synchronous limb autotomy produces individual regenerates from the same animal that may require less than, or more than, a single molt cycle to reach full limb development. Due to the reduced levels of female pigmentation in the Rili strain, this morph seems best suited for microinjection studies. Experiments examining protocols for egg microinjection and assessment of genomic variation among morphs are in progress.

[1]Mykles, DL, Hui, JHL, 2015. *Neocaridina denticulata*: A Decapod Crustacean Model for Functional Genomics. Integr. Comp. Biol. doi:10.1093/icb/icv050. [2]Mykles, DL, *et al.* 2016. Resources and Recommendations for Using Transcriptomics to Address Grand Challenges in Comparative Biology. Integr. Comp. Biol. doi:10.1093/icb/icw083

23.2 DABE, E.C.*; GILLETTE, R.; MOROZ, L.L.; Univ. of Florida, Univ. of Illinois; *emily.dabe@gmail.com*

Profiling serotonergic neurons across behavioral arousal states with single-neuron transcriptomes

Pleurobranchaea californica or the california sea owl, has distinctive feeding behaviors, a characterized feeding network and the largest neurons in the animal kingdom. Together these features have made this mollusc an excellent model for studying the connection between neuronal network activity and animal behavior. Many electrophysiology studies characterized the link between the activity of a pair of giant serotonin neurons, the metacerebral cells (MCCs) and the sea owl's hunger state. These repeatedly identifiable MCCs, allow us to answer basic neuroscience questions about the connection between neuronal excitability and gene expression and tie our findings to observable behavior all with single-cell resolution. The MCCs are also conserved across opistobranch molluscs, and thus can provide insights into the evolution of serotonergic neurons and neuronal feeding networks. Previous studies determined that when molluscs are fed until completely satiated, these MCCs show reduced firing rates, and that *P. californica* stops both producing and releasing its primary signal molecule serotonin when satiated. We investigated whether changes in RNA expression contribute to this phenotype by comparing single-neuron MCC transcriptomes from hungry and satiated animals. Preliminary data also showed a large number of significantly differentially expressed genes, including different mRNA-binding proteins that are expressed during satiation and hunger states. By promoting translation of mRNA transcripts during hunger or sequestering transcripts to prevent translation during satiation these mRNA binding proteins could contribute to the changes in serotonin synthesis observed in *P. californica*. This finding suggests a potential new mechanism of regulating neurotransmitter expression and neuronal excitability via post-transcriptional modification of the serotonin pathway genes.

81.3 DALLMANN, CJ*; HOINVILLE, T; DÜRR, V; SCHMITZ, J; Bielefeld University, Germany; *cdallmann@uni-bielefeld.de*
A Load-Based, Leg-Local Mechanism for Inter-Leg Coordination in Insects
Adaptive and stable walking requires that a leg's stance-to-swing transition is coordinated with the step cycles of the other leg(s). The properties of load sensors in both mammals and insects suggest a particular elegant, leg-local mechanism to do so: A leg in stance lifts off the ground when sensing a sudden reduction of its own load induced by another leg's touchdown due to mechanical coupling. Here we test the plausibility of this mechanism in freely walking stick insects (*Carausius morosus*) using simultaneous recordings of leg kinematics, ground reaction forces, and electromyographic activity. First, we show that the insect load sensors (campaniform sensilla) can reliably encode the unloading of a leg in stance during walking. Based on joint torques, we predict that two sensor groups on the trochanter change their activity upon the onset of unloading. This could trigger a motor effect promoting the leg's stance-to-swing transition. Second, we show that the onset of unloading is directly linked to the transfer of mechanical load among legs: (i) unloading is closely preceded by the touchdown of the neighboring posterior leg; (ii) according to a static simulation, this leg takes on load with highest efficacy; (iii) the levator muscle of the leg in stance is activated only after the onset of unloading. Taken together, our results demonstrate that leg-local load signals can contribute significantly to inter-leg coordination by exploiting the mechanical coupling between legs. We predict that this mechanism is used to similar advantage across insect species, in analogy to load-based mechanisms proposed in mammals.

P2.266 DAMERON, MT*; CLARK, K; STOWERS, SR; MOHAMED, A; REDMOND, SB; Radford University; *mdameron2@radford.edu*
ATP Production Increases with Addition of Varying Concentrations of Vespa Amino Acid Mixture (VAAM)
Vespa amino acid mixture (VAAM) is used as an exercise supplement by humans to increase athletic performance. The specific mechanism is not yet known but our previous work suggests VAAM affects the electron transport chain and ATP synthase activity. While increased exercise capacity shortly after VAAM exposure has been observed in multiple species, the relationship between VAAM and ATP production has been assumed without supporting data, until now. Using *Saccharomyces cerevisiae* , ATP production was measured with an ATP Titer Glo Assay under exposure to varying concentrations of VAAM (0%-0.3%) at different time intervals. Our data confirm that VAAM increases ATP production as VAAM concentration is increased (from 0% to 0.3% VAAM; p-value= 0.01). As time progressed over hours, cells were lost, most likely due to cell death, which resulted in lower ATP production, particularly in the high-concentration VAAM treatment group. Addition of antioxidant mixture had an effect on steps following electron transport. With this data, further experiments will be done to test the effect of VAAM on other organisms, also in combination with other chemical species to have a further understanding of the potentially harmful effects of VAAM.

62.2 DANNER, RM*; COOMES, CM; DERRYBERRY, EP; Univ. of North Carolina, Wilmington, Tulane University; *dannerr@uncw.edu*
High Ambient Temperatures Reduce Cognitive and Motor Performance of an Endotherm
Recent heat waves have led to mortality of animals across the globe including humans, which has drawn new attention to how animals cope with thermal stress. Currently, there is a strong focus on characterizing physiological lethal limits of thermal stress in endotherms to predict how heat waves in a changing climate will affect populations. Less well studied are the sublethal effects of thermal stress on animal behavior, which may influence both survival and reproductive success. Here we show that birds (zebra finches) exhibit reduced cognitive and motor performance on foraging tasks when exposed to naturally occurring high temperatures. First, birds showed poorer inhibitory control in a detour-reaching task at high temperatures, indicating that heat can limit cognitive performance. Second, birds were less efficient at foraging in a color-association task at high temperatures, despite high accuracy in associating food with colors, providing further evidence that high temperatures limit cognitive performance and that cognitive functions vary in their susceptibility to limitation by heat stress. Third, birds performed the timed color-association task more slowly at high temperatures because they stopped to perform thermoregulatory behaviors and because of slower muscle movement, indicating that heat limits motor performance. We anticipate that these findings will stimulate new research and planning objectives for climate change. These results provide a mechanistic link between the physiology of thermal stress to recently observed phenomena at the population-level, including range shifts and breeding failure. Further, these results expand our understanding of animal cognitive conditions during thermal stress, and will be of interest to those involved in animal production and welfare, human health, and human workforce planning.

S9.1 DANTZER, Ben; University of Michigan; *dantzer@umich.edu*
Introduction: what is the importance of individual variation in cooperativeness?
Animals spend much of their time interacting socially with members of their own species. Forms of animal social behavior range from courtship, mating, and parental care behaviors, to more complex coordinated and cooperative behavior among related or unrelated individuals in group-living species. The evolutionary causes and consequences of such cooperative behavior have been a focus of biological research for nearly two centuries. A number of theoretical models such as those based upon reciprocal cooperation or shared genetic interests predict the conditions under which cooperation is likely to evolve. Although these models have resulted in productive research paradigms that have shaped the formal study of animal behavior for the last half century, recent models suggest that the evolution of cooperation is also heavily influenced by the degree of individual-variation in cooperative behavior as well as the underlying developmental and proximate mechanisms. Individual variation in cooperative behavior and the mechanisms underlying it are not only understudied by empiricists, but also studied in isolation, despite their potential importance for the evolution of cooperation and social organization. The primary aim of this symposium will be to establish new research avenues to study variation in cooperation using both mechanistic and evolutionary explanations. In this presentation, I will introduce the themes of this symposium and present an overview of the apparent importance of individual-variation in cooperative and social behavior using examples from our own research as well as from others.

S8.8 DANTZER, Ben*; SWANSON, Eli M; University of Michigan, University of Minnesota; *dantzer@umich.edu*

Does hormonal pleiotropy constrain the independent evolution of performance and life history traits? A quantitative genetic approach.

The influence of a single hormone on expression of two or more performance or life history traits may constrain or facilitate the evolution of these traits. Two hypotheses have been proposed to explain whether such hormonal pleiotropy affects trait evolution. One hypothesis proposes that the different parts of an endocrine axis (hormone titer, receptor expression, etc.) are independent from one another and therefore two traits that are both affected by the same hormone can evolve separately. For example, one trait could be influenced by modifying its sensitivity to the signal whereas the expression of the other trait could be influenced by signal intensity. A second hypothesis proposes that the features of an endocrine axis are not independent from one another such that the expression of two phenotypic traits affected by the same hormone are yoked. One way to test these hypotheses is to study the mechanistic causes of variation in these traits, such as asking whether hormone titers or receptor expression explains more variation in the trait. We will discuss an alternative approach using quantitative genetics that may be useful for longitudinal studies of wild animals. We extend these hypotheses by developing a model to derive predictions about the conditions under which hormonal pleiotropy would constrain the independent of phenotypic traits. We focus on performance and life history traits and how the effects of hormonal pleiotropy on the evolution of these traits depends upon the genetic correlations between the hormone and traits as well as the direction and strength of selection on the two traits. Finally, we discuss methodological aspects of this approach and review the literature for examples that have estimated these model parameters to characterize the studies that have or have not found support for these model predictions.

P2.68 DAPPA-FOMBO, SE*; HOLMQUIST, E; DAVIS, MC; Kennesaw State University; *sdappafo@students.kennesaw.edu*

Regenerative capacity in the paired fins of the American paddlefish Polyodon spathula

Vertebrate paired fins consist of two separate skeletal compartments: A proximal endoskeleton derived from cartilage and a more distal dermal skeleton consisting of a series of collagenous or mineralized rays. All jawed vertebrates lineages possess both skeletal types, with the exception of tetrapods which lost the dermal skeleton in concert with the origin of limbs during the late Devonian transition onto land. An additional adaptation that varies across phylogeny is the capacity to regenerate all or portions of the appendage skeleton following trauma, such as injury or disease. At least some degree of dermal skeleton regeneration has been observed in the major lineages of finned vertebrates. However, regenerative capacity of the endoskeleton exhibits a "patchy" phylogenetic distribution which confounds attempts to understand the evolution of the character. Urodele amphibians and the basal actinopterygian *Polypterus* exhibit complete or nearly complete regeneration of their paired appendages following amputation. However, endochondral regenerative abilities have not been reported for other finned or limbed lineages. Here we report the first evidence of limited regenerative capacity in the paired fins of a second basal actinopterygian lineage, the American paddlefish *Polyodon spathula*. Our results provide further phylogenetic context to test hypotheses about the antiquity of appendage endoskeletal regenerative capacity and patterns of loss of this capacity within derived lineages.

89.6 DAS, S.*; DURICA, D.S.; MYKLES, D.L.; Colorado State University, Fort Collins, University of Oklahoma, Norman; *sdas@colostate.edu*

Transcriptomic analysis of signal transduction pathways in the regulation of the crustacean molting gland

The Y-organ (YO) is an endocrine gland that regulates molting in decapod crustaceans. The biosynthesis of ecdysteroids is negatively regulated by molt inhibiting hormone during intermolt and increased titers of circulating molting hormone triggers the animal to enter premolt. YO activation and commitment at early and mid premolt require mTOR and TGFβ/activin signaling, respectively. However, the roles of other signaling cascade(s) driving the production and inhibition of ecdysteroid biosynthesis are largely unknown. A transcriptomics approach was used to identify 1) known signal transduction pathway components, and 2) differentially expressed pathway components across molt cycle. An RNA-seq transcriptome was generated from 5 molt cycle stages (intermolt; early, mid, and late premolt; and postmolt) of *Gecarcinus lateralis* YO. The differential expression pipeline included removal of low counts; normalization of count data using RUVSeq, and identification of differentially expressed (DE) contigs using the limma-voom package. Following filtering and normalization, count data from 48,590 contigs were used to identify 14,791 DE contigs at <0.01 FDR cut-off. BLASTx against the KEGG Ortholog (KO) database using sequences from human, and six arthropod species resulted in annotation of pathway components. A total of 878 contigs with KO relevant to 23 signal transduction pathways were identified, of which 291 were DE. In addition to this, using Fisher's exact test, 10 signaling KEGG pathways, including MAP kinase, mTOR, cAMP, Notch, Wnt, AMP kinase, were identified as significantly enriched at <0.05 FDR cut-off, implicating their role in regulating molt cycle stage transitions. Supported by NSF (IOS-1257732).

77.5 DAVIES, SW*; MARCHETTI, A; RIES, J; CASTILLO, KD; Univ. of North Carolina, Chapel Hill, Northeastern University; *daviessw@gmail.com*

Effects of Long-term Warming and Acidification on Coral-algal Symbiosis: A Transcriptomic Perspective

Elucidating the responses of symbiotic partners to environmental stressors is becoming increasingly important as climate change disrupts biotic interactions worldwide. We exposed the Caribbean coral *Siderastrea siderea* and its algal symbiont to temperature and pCO_2 treatments for 95 days and quantified the transcriptomic responses of each partner using RNAseq. Both elevated temperature and pCO_2 elicited strong but divergent responses of the host's transcriptome. High temperatures disrupted molecular homeostasis and substantially reduced calcification rates. Conversely, elevated pCO_2 enhanced host transcription of genes associated with respiration and hydrogen ion transport, with only minimal effects on calcification rates—underscoring the role of proton transport in calcification maintenance under elevated pCO_2, while also suggesting costs associated with this acclimation. Contrary to the host, the symbiont's transcriptome exhibited little change in response to elevated pCO_2. Instead, population-specific transcriptomic responses were observed across fore-reef and near-shore environments—consistent with observed differences in symbiont photosynthetic efficiency across these two reefs. We conclude that host transcriptomic plasticity promotes acclimation to ocean acidification, but not necessarily warming. Given the host's strong transcriptomic responses to acidification and warming, coupled with the symbiont's lack of response, we hypothesize that hosts actively buffer their symbiont's environment.

P2.51 DAVIS, KM*; HARPER, GR; Hendrix College;
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Comparison of Contortrostatin Genes in the Five Subspecies of Copperhead
Agkistrodon contortrix, the copperhead, is one of many species of *Viperidae:Crotalinae* to use disintegrin proteins in their venom to subdue and digest prey. Disintegrins, non-enzymatic proteins that inhibit the normal function of cells by binding to transmembrane integrin proteins, block normal cell-to-cell interactions within envenomated prey. Although all disintegrins are thought to act in a similar manner, they can be classified according to their length, number of disulphide bonds, and presence or absence of dimeric bonding. These structural differences lead to differences in binding affinities and thus activity of the protein. Copperheads have a homodimeric disintegrin named Contortrostatin, which has drawn a great deal of attention from medical researchers as a treatment to prevent the spread of cancer within an individual. Contortrostatin was isolated and cloned from cDNA of the Southern Copperhead (*Agkistrodon contortrix contortrix*), and no sequences from the other four subspecies (*A. contortrix pictigaster, A. contortrix phaeogaster, A. contortrix laticinctus*, and *A. contortrix mokasen*) have been published. The aim of this study was to isolate and sequence the genomic Contortrostatin gene from all five subspecies to understand whether this gene has diversified within the species, and if so what effect the variations might have on the protein. In addition, our sequences allow us to test whether these genes are evolving through drift, selection, or a combination of the two.

P2.163 DAVIS, S*; SATTERLIE, RA; University of North Carolina Wilmginton, University of North Carolina Wilmington;
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Statocysts of Scyphomedusae
Each rhopalium of scyphomedusae contains a terminal statolith, suggesting that this part of the rhopalium, or the full rhopalium, functions in sensing body position relative to gravity. The righting response of pelagic scyphomedusae has been documented, but the location of sensory cells involved in this response has not been shown unequivocally. One proposal is the statolith acts as a weight, and changes in the sag of the rhopalium is detected as the animal tilts. Our video data indicate, however, that the rhopalia are stiff structures that do how significant sag. Another suggestion is that patches of putative sensory cells, called touch pads, are involved in tilt-related detection. Our comparative examination of two scyphomedusae, one pelagic and one primarily benthic, shows the presence of putative sensory cells associated with both the rhopalium and the surrounding tissues, with differences in the distribution of these sensory cells in the two species. This suggests detection of body tilt involves both the rhopalia and the surrounding tissues.

P2.150 DAVIS, M/M.A*; O'BRIEN, S; Radford University;
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Do mosquitofish show active behavioral preference for substrate color in their environment?
Do mosquitofish actively seek substrates of particular colors within their environment? Previous research on wild Western species of mosquitofish (*Gambusia affinis*) has demonstrated that fish prefer specific substrate colors and that the ability to choose substrate colors in their habitat may have a significant impact on the health and reproduction of this species. We examine, in a captive setting, whether the Eastern mosquitofish (*Gambusia holbrooki*) will respond to different colors of substrate by changing their color (through melanophores) and if this species will actively seek out particular colors of substrate in their environments. For our experiment we observed fish swimming behavior in an aquatic environment over a period of time (weekly video recordings over 1.5 months) with various substrate (aquarium gravel) colors and patterns. Specifically, our study not only observed whether or not there is a preference for a specific substrate but also whether the essentials for an aquarium (filters) had any effect on their behavior. Overall, this study allowed us to see that while mosquitofish change to coincide with the surrounding substrate in their environment, they have no behavioral preference (actively seeking to spend time in certain areas) for substrate color. In addition to better understanding how these fish respond to changes within their environment, such as changing colors of substrate, understanding the influence of substrate color on mosquitofish is an important factor to consider in captive animal husbandry as a review of animal care protocols does not currently designate or take into account the preference of fish for particular substrate color.

P1.12 DAVIS-BERG, EC*; MINBIOLE, JE; Columbia College Chicago, IL; *edavisberg@colum.edu*
Increasing student completion rate on quizzes and exams by using bullet points or number prompts
Leaving an answer blank can be a simple question to grade, but it represents a failure in the ability to effectively assess student understanding on course assessments. We evaluated whether student completion rate would improve when students were provided with bullet points or numbers rather than simply given a large blank answer space for multi-part questions. Our findings indicate that students were more likely to complete a question when bullet points or numbers were present in the provided answer space. We collected data from 111 samples from classes including Marine Biology, Sensation and Perception, and Animal Behavior. In each of these classes, we randomly gave half of the students the quiz or test version with the control (blank) and half received a version where one question had bullet points or numbers (experimental). We recorded the grade on the question, the quiz, and the portion of the experimental question that was completed. While mean student completion rates improved from 88.8% to 99.2% ($P < 0.01$, 2-tailed unpaired t-test) when bullet point or number prompts were given, there was no significant increase in score on the experimental question, mean of 72.2% without dots and 79.9% with dots. We found this quick fix to significantly increase student response rate on assessments, which not only can increase the chance of student success, but provides instructors with more completed assessments allowing them to better assess student achievement of course outcomes.

20.2 DAYGER, CA*; LUTTERSCHMIDT, DI; Portland State Univ, Oregon; *cdayger@pdx.edu*
Modulation of the hypothalamus-pituitary-adrenal axis is associated with life-history transitions in garter snakes
Despite increasing evidence that glucocorticoids regulate life-history transitions, the mechanisms linking changing glucocorticoids to particular life events remain unclear. We studied the role of glucocorticoids in coordinating two key life-history transitions in garter snakes: spring and fall migration from and to the breeding site. In comparing our female data with previous work in males, we uncovered variation in stress responses with season, sex and migration state. We examined the mechanisms underlying this variation by assessing adrenal sensitivity to adrenocorticotropic hormone (ACTH). Males are less responsive to ACTH than females during the spring mating season, indicating that sex differences in stress responsiveness are related to modulation of adrenal sensitivity in males. Interestingly, pre-migratory, breeding females responded to and recovered from capture stress more quickly than migrating females, suggesting that negative feedback on the HPA axis may be linked to changes in female reproductive state. Females reproduce biennially and thus variation in reproductive history may be related to both stress sensitivity and energetic condition, leading us to probe the relationship between the HPA axis and reproductive condition. Mating behavior, but not stress responses, predicted whether a female reproduced during the summer. Stress responses did vary with receptivity however, suggesting that variation in the sensitivity of the HPA axis is related to whether a female will reproduce in a given year. These data collectively describe how HPA axis activity and sensitivity vary with season, sex, migration status and reproductive history. Our results support the hypothesis that the HPA axis coordinates the changes in physiology and behavior vital to transitioning between life-history events.

72.1 DE BRUIJN, R*; PEIMAN, KS; PRYSTAY, TS; PHILIPP, MA; GILMOUR, KM; HINCH, SG; PATTERSON, DA; COOKE, SJ; Carleton University, Dalhousie University, University of Ottawa, University of British Columbia, Fisheries and Oceans Canada; *robertdebruijn@cunet.carleton.ca*
The stress of salmon migration: spawn or die trying.
Recent studies show that glucocorticoids (GCs) play an important role in mediating life-history trade-offs. For example, stress induced levels of GCs predict survival in both migrating and spawning Pacific salmon (*Oncorhynchus spp*). Yet, we still understand little about the overall functioning of the hypothalamus-pituitary-interrenal (HPI-) axis, responsible for GC release. While GC levels increase during migration, it is unclear if the HPI-axis is still functioning normally, or has become dysregulated. At present, little is known about negative feedback efficacy in spawning salmon, or how close to maximal interrenal production capacity the increase levels of GCs are. Interestingly, it is possible that a dysregulation of the HPI-axis, which would normally prevent individuals from mounting appropriate responses to further stressors, may be an important trade-off between survival and spawning in these fish. Especially since prolonged elevation of GCs has traditionally been associated with chronic stress, resulting in reduced reproductive success. In contrast, in salmon elevated GCs may be critical in providing the resources necessary for successful migration. This project aims at assessing HPI-axis functioning in spawning sockeye to further elucidate the role GCs and the HPI-axis play in the migration and reproductive success in a semelparous fish. Fish were caught as they arrived at the Gates Creek spawning channel at different times during the spawning season, to be able to assess both successful spawning as well as pre-spawn mortality. Once caught HPI-axis functioning was assessed fish were released into the channel, where spawning behavior and success were obtained.

140.5 DE MEYER, J; GOETHALS, T; AUGUSTIJNS, T; HABRAKEN, J; HELLEMANS, J; VANDEWIELE, V; DHAENE, J; BOUILLART, M; ADRIAENS, D*; UGent, Evomorph, UGent, UGCT; *dominique.adriaens@ugent.be*
Dimorphism throughout the European Eels' Life Cycle: Head Shape Related to Dietary Differences?
An organisms' morphology can be related to its ecology and vice versa. Also in the dimorphic European eel, head shape can be related to differences in feeding ecology, with broad-headed phenotypes consuming harder prey than narrow-headed ones. As such, broad-headed eels are expected to have characteristics that increase their bite force to access harder prey. Using 3D-reconstructions of the cranial musculoskeletal system, we compared the morphology of both phenotypes at two life stages: the sub-adult yellow eel stage and its predecessor, the elver eel stage. With elvers at the onset of their predatory phase, this allowed us to find out whether broad- and narrow-headed phenotypes have similar characteristics in both life stages and whether the dimorphic traits become more pronounced during ontogeny. Additionally, we use a 3D-bite model to test whether broad-heads can generate higher bite forces than narrow-heads. We found that broad-headed phenotypes in both stages are characterized by larger jaw muscles, a broader skull and elongated upper and lower jaws with a higher coronoid, although these features did not become more pronounced during ontogeny. The bite model indicates that the larger jaw muscles of broad-heads allow the generation of higher bite forces to deal more efficiently with hard prey. Additionally, these larger muscles and the elongated lower and upper jaws may improve grip during spinning behavior, which is applied on hard prey. In conclusion, this study showed that the European eels' head shape can be related to its feeding ecology and that in both life stages, dietary differences can take place

P2.82 DEADMOND, A.; ZOU, E.*; Nicholls State University; *em.zou@nicholls.edu*
Which house-keeping gene is most stably transcribed during the molting cycle of the blue crab, Callinectes sapidus?
Crustaceans experience discontinuous growth because of the periodic shedding of their confining exoskeleton, a process known as molting or ecdysis. Because of periodic molting, much of crustacean physiology is cyclic, with many physiological and biochemical parameters varying during the molting cycle. House-keeping genes (HKGs) are commonly used as the internal control for quantitative real-time PCR (qPCR). In spite of the lack of assessment on the changeability of HKGs during crustacean molting cycle, several genes, including *beta-actin*, *18S rRNA* and *arginine kinase*, have been used as the reference gene in qPCR quantification of expression of crustacean genes. The objective of this study was to determine which HKG is most stably transcribed during the crustacean molting cycle, using the blue crab, *Callinectes sapidus*, as the model crustacean. The expression stability of seven HKGs from the hepatopancreas, including *beta-actin*, *glyceraldehyde 3-phosphate dehydrogenase*, *28S rRNA*, *histone*, *ribosomal protein*, *arginine kinase* and *18S rRNA*, during the molting cycle of the blue crab, *Callinectes sapidus*, was assessed using the geNorm tool. The *beta-actin* gene gave rise to the lowest geNorm score, suggesting this gene is the most stably expressed, and therefore the best qPCR internal control of the seven HKGs tested.

26.7 DEAN, MN*; HOSNY, A; KNOETEL, D; SEIDEL, R; LUGER, AM; WAINWRIGHT, D; BLUMER, M; BAUM, D; MPIKG, Germany, Wyss Inst, USA, ZIB, Germany, Harvard, USA, MUI, Austria, ZIB, Germany; *mason.dean@mpikg.mpg.de*

Bricks and anchors: strategies for load bearing and muscle attachment in the cartilage skeletons of sharks and rays

The skeletons of sharks and rays are tessellated cartilage, made of an unmineralized core, wrapped in a rind of small mineralized tiles called tesserae. Tessellated cartilage performs a similar mechanical role to bone; however, characterizing the relationship between the tessellation and the forces acting on the skeleton is difficult because tesserae are small, occur in huge numbers, and exhibit complex 3d interactions with surrounding tissue. We investigate the relationship between muscular forces, skeletal morphology, and tessellation in microCT scans of paired skeletal elements from an age series of round stingray *Urobatis halleri*. We use iodine-stained samples to resolve musculature and a custom segmentation algorithm to quantify tessellation patterns and morphometrics. We show that during growth, blocklike tesserae are the first to appear in areas of high positive curvature where high loads are expected, followed by flatter tesserae in regions of low curvature. Tesserae increase in size as animals age, but new tesserae appear only in flatter regions of the skeleton, suggesting that high-load areas are constrained to be less mutable. In adults, the largest tesserae are found along pronounced ridges, which often border zones of muscle attachment. Muscles insert via broad bundles of Sharpey's fibers, anchored into concave regions characterized by poorly developed tesserae. These findings and the demonstration that series of tesserae align along axes of loading argue that the morphology and relationship of tesserae can be used to infer loading environments in tessellated cartilage, providing fundamental design concepts for tiled, load-bearing engineering composites.

36.7 DEARBORN, DC*; GAGER, AB; MCARTHUR, AG; GILMOUR, ME; MANDZHUKOVA, E; MAUCK, RA; Bates College, McMaster Univ., Univ. of California, Santa Cruz, Kenyon College; *ddearbor@bates.edu*

How to Get Diverse MHC Genotypes Without Disassortative Mating

Genes of the major histocompatibility complex (MHC) defend against disease by helping the immune system recognize pathogens. MHC heterozygotes have higher fitness than homozygotes, which in turn should favor MHC-disassortative mating, but a surprising number of species mate randomly with respect to MHC. The explanation may lie in evolutionary processes following gene duplication: if two duplicated MHC genes become functionally diverged from each other, offspring will inherit diverse multilocus genotypes even under random mating. We used locus-specific primers for high throughput sequencing of two expressed MHC Class II B genes in Leach's storm-petrels, *Oceanodroma leucorhoa*, and found that exon 2 alleles fall into two gene-specific monophyletic clades. Analysis of mated pairs consistently showed no evidence of disassortative mating, despite good statistical power and multiple analytical approaches. Even with random mating, though, birds had MHC genotypes with functionally diverged alleles, averaging 13 amino acid differences in pairwise comparisons of exon 2 alleles within individuals. We built a phylogenetic permutation model to test whether this high MHC diversity in individuals is driven by evolutionary divergence of the two duplicated genes. The model showed that genotypic diversity was strongly impacted by sequence divergence between the most common allele of each gene, with a smaller additional impact of monophyly of the two genes. This divergence of allele sequences between genes may reduce the importance of actively seeking MHC-dissimilar mates, in which case the evolutionary history of duplicated genes is shaping the adaptive landscape of sexual selection.

S5.7 DEARING, M. Denise*; KOHL, K; University of Utah, Vanderbilt University; *denise.dearing@utah.edu*

Beyond Fermentation: Gut microbes reduce toxicity of herbivore diets

At every meal, herbivorous mammals are confronted with the prospect of being poisoned by the naturally occurring toxins in plants. More than 40 years ago, Freeland and Janzen hypothesized that gut microbes play a key role in facilitating the ingestion of dietary toxins by herbivorous mammals. Early investigations of this hypothesis were limited by experimental techniques and the inability to culture many microbes under laboratory conditions. However, the advent of high-throughput sequencing and metabolomics have enabled rigorous and experimental tests of this hypothesis. Using these approaches, we tested the hypothesis that gut microbes facilitate ingestion of natural dietary toxins by herbivorous woodrats (genus, Neotoma). We have discovered that woodrats harbor a dense, diverse and active community of microbes in their foregut. Moreover, a functioning and diverse gut microbial community plays a critical role in the host's ability to ingest a toxic diet. We have been able to transfer the gut microbial community of woodrats within and across species lines, thereby improving their ability to ingest toxic diets. The results support the hypothesis that microbes enhance the ability of herbivores to ingest toxic diets and may rapidly permit the host to expand diet breadth without host evolutionary changes. In addition, this basic science holds promising applications for improving human health and enhancing animal husbandry through the development of novel probiotic mixtures.

111.3 DEAROLF, J.L.*; WEIGAND, K.L.; TOTTEN, D.C.; MARSHALL, S.; BREWINGTON, A.K.; Hendrix College, Conway, AR; *dearolf@hendrix.edu*

Effect of multi-course prenatal corticosteroids on breathing muscle fiber-type profiles and myosin heavy chain expression

A single course of prenatal corticosteroids (dexamethasone or betamethasone) has been shown to significantly reduce premature infant mortality, but the use of multi-course prenatal steroids is still under debate. We test the hypothesis that exposure to multi-course betamethasone accelerates the development of fetal ventilatory muscles in a model species, the guinea pig (*Cavia porcellus*), specifically resulting in less fast-twitch types IIA and IIX muscle fibers and reduced expression of IIA and IIX myosin heavy chains. We also measured fiber size (diameter) of the treated muscles, as other studies have observed atrophy in steroid-exposed muscles. Pregnant guinea pigs were exposed to three courses of betamethasone, which were timed to overlap the last week of myogenesis, and samples of fetal (59-days gestation) ventilatory muscles (diaphragm, rectus thoracis, scalenus, external abdominal obliques, and rectus abdominis) were collected. Standard muscle histochemistry techniques (myosin ATPase) were used to determine the proportions and diameters of each fiber-type. Muscle proteins were separated in SDS-polyacrylamide gels, and scanning densitometry was used to determine the proportions of each type of myosin expressed by the treated and control muscles. The fiber-type profiles ($P = 0.069$), fiber diameters (fast-twitch: $P = 0.175$; slow-twitch: $P = 0.183$), and myosin expression (embryonic: $P = 0.068$; neonatal / IIA/IIX: $P = 0.302$; slow: $P = 0.475$) of the steroid-treated muscles were not significantly different from those of control muscles. These results do not support our hypothesis and suggest that multi-course steroid exposure during the last week of myogenesis has no effect on the development of fetal ventilatory muscles.

42.3 DEATON, LE; Univ. of Louisiana at Lafayette; *led9784@louisiana.edu*

Effects of Biogenic Amines on Isolated Ventricles of the Atlantic Ribbed Mussel, Geukensia demissa, and the Northern Quahog, Mercenaria mercenaria.

Recent reports suggest that octopamine, a biogenic amine that is ubiquitous in arthropods, is a cardioexcitatory agent in the blue mussel, *Mytilus edulis*. To investigate the effects of octopamine on bivalve hearts, we isolated ventricles from *Guekensia demissa* and *Mercenaria mercenaria* and suspended the preparations in organ baths. The mechanical activity of the isolated ventricles was monitored with force transducers (Grass FT 03) and an ink-writing oscillograph (Grass 7). The ventricles were challenged with doses of octopamine, dopamine, histidine, epinephrine, and serotonin. Octopamine had mixed effects on ventricles of both species. Dopamine was cardioexcitatory at concentrations. Histamine and epinephrine increased the amplitude of contraction. Serotonin inhibited *G. demissa* ventricles. The results of these experiments with epinephrine and dopamine are largely consistent with published data on the isolated ventricles of a number of other bivalves. In most species, the heart is excited by both of these agents, albeit at high concentrations. Serotonin is cardioexcitatory in most species, but can be inhibitory (as in the ventricles from Louisiana populations of *G. demissa*) in some species. The effects of octopamine and histidine on the hearts of bivalves have not been extensively studied. The key question is: what is the nature of biogenic amine receptors in bivalve ventricles? Are there receptors for all of these neuroeffectors, or are the effects reported due to cross-talk?

16.8 DEBAN, SM*; BLOOM, SV; O'DONNELL, MK; OLBERDING, JP; STINSON, CM; SCALES, JA; Univ. South Florida, Tampa, Calif. State Univ., Stanislaus; *sdeban@usf.edu*

Evolution of a high performance and functionally robust musculoskeletal system

Plethodontid salamanders have evolved high-performance, ballistic tongue projection. Examples of extreme performance abound: *Hydromantes* can shoot its tongue from the body by 80% of SVL, *Thorius* can accelerate its tongue at 600 G, and *Bolitoglossa* can amplify muscle power 100 times with the use of collagen springs. Ballistic projection, in which the tongue skeleton leaves the body entirely, has evolved multiple times independently in plethodontids, and in each case is accomplished by an elastic-recoil mechanism that both amplifies muscle power and circumvents thermal constraints on muscle contraction, allowing projection at cold temperatures (as low as 2°C in *Hydromantes*). The bow-and-arrow mechanism of tongue projection has evolved via relatively minor changes in the morphology of the subarcualis rectus muscle (SAR), in which myofiber connections to the tongue skeleton are lost and collagen aponeuroses within the SAR are elaborated to form spiral sheets that act as springs to store muscle energy and release it quickly as mechanical work. Motor control has evolved by a simple shift in the timing of muscle activity that allows the collagen to be stretched prior to tongue projection. Muscle contractile experiments show that muscle contractile physiology is conserved evolutionarily. These findings in salamanders, together with data from chameleons and frogs, reveal that relatively minor changes in morphology and motor control can dramatically increase the performance and thermal robustness of animal movements.

15.7 DEBIASSE, MB*; STUBLER, AD; KELLY, MW; University of Florida, University of North Carolina Wilmington, Louisiana State University; *melissa.debiasse@gmail.com*

Testing the effect of ocean acidification on a sponge-coral species interaction

Atmospheric carbon dioxide levels have risen at an unprecedented rate in the last 250 years, resulting in increasing global temperatures. By acting as a sink for atmospheric CO_2, in addition to becoming warmer, oceans are becoming more acidic. Extensive research has documented major changes between individuals and their physical environment under ocean acidification, less attention has focused on the effects of ocean acidification on species interactions. In this study, we test how ocean acidification influences an important species interaction between the stony coral *Porites furcata* and the excavating sponge *Cliona varians*, species that have opposing ecosystem roles on Caribbean coral reefs: *P. furcata* creates reef structure through the accretion of calcium carbonate, while *C. varians* overgrows live corals and bioerodes calcium carbonate substrates. We collected RNAseq data from corals and sponges exposed to ambient or low pH conditions, both in isolation and in treatments where corals were overgrown by sponges. Previous work demonstrated that increased ocean acidification reduced calcification in the coral and increased bioerosion rates in the sponge. Using transcriptomic data, here we will identify the genomic mechanism of sponge bioerosion and test whether bioerosion rates in the sponge increase under ocean acidification due to a physiological change in the sponge or a weakening of the coral skeleton. We will also test whether decreased calcification in the coral is driven by the stress of low pH or the reallocation of resources to fight sponge overgrowth. Our results will inform models predicting ecosystem-level responses to future conditions by providing important data about species interactions under global change.

P3.107 DEBRAY, R.R.*; FORMICA, V.A.; BRODIE III, E.D.; Duke University, Swarthmore College, University of Virginia; *reena.debray@gmail.com*

Consistency of Individual Activity in the Context of Social Networks of Forked Fungus Beetles

Social network analyses are often used to capture structural patterns in populations in which individuals interact to varying degrees with conspecifics. However, it is not well known why individuals hold particular network positions, and a potential criticism of social network theory is that networks may only capture individual behaviors, such as activity. If this were true, network-level analyses would not provide novel insights in the study of social behavior. This study measured three types of activity in forked fungus beetles (*Bolitotherus cornutus*) to understand possible relationships between behavior and network position. We tested a sample of field-collected beetles (n=91) three times to assess the repeatability of activity. We also tested individual beetles (n=64) from a field population on which social network interactions were observed three times per day for seven weeks. The three behaviors were all significantly repeatable (latency to movement: R=0.451, p=6.01x10-11; distance moved: R=0.474, p=2.19x10-9; top speed: R=0.567, p=6.2x10-13). None of the behaviors were significantly correlated with any of three social network metrics (strength, betweenness, and clustering coefficient). These results suggest that network position may capture information above and beyond individual behavior or activity. This study is an important first step in understanding the factors that influence social network position.

P3.93 DECKARD, FM*; JOHNSON, MA; Trinity University, Trinity University ; *fdeckard@trinity.edu*
Muscle Physiology and Social Behavior in Caribbean Anole Lizards: How Do Muscle Fiber Type and Size Interact?
Animal movements and the muscles that produce those movements are tightly interrelated, as behavioral movements require muscular contractions, and in turn, the use of a muscle can influence the structural and biochemical traits of the muscle. For example, continuously active muscles generally have a higher percentage of fatigue-resistant fibers than muscles used periodically, and muscles used more frequently are often composed of larger fibers. Yet, these traits are rarely examined across species. Here, we test the hypothesis that the types of fibers that compose a muscle (fast or slow twitch; oxidative or glycolytic) and their size evolve in association with the frequency or duration of the contractions of that muscle, using three closely-related pairs of Anolis lizard species. The lizards in each pair share a suite of morphological and ecological specializations to a particular microhabitat, but differ dramatically in the frequency and duration for which the dewlap (a throat fan used in aggressive and courtship displays) is extended. We collected behavioral field data on dewlap use for each species, and then collected the ceratohyoid (CH), the muscle responsible for dewlap extensions, from each species to determine the composition and size of CH fibers. We found a negative correlation between dewlap frequency and duration, such that species either display the dewlap quickly and often, or rarely but for longer durations. We found that species that extend the dewlap rarely and slowly have a higher proportion of slow oxidative fibers, the type associated with endurance, in the CH. We are now determining whether CH fiber size interacts with their type to produce dewlap extension, to understand how behavior and the physiological traits that underlie it have coevolved.

83.4 DEETJEN, M.E.*; BIEWENER, A.A.; LENTINK, D.; Stanford University, Harvard University; *mdeetjen@stanford.edu*
High-Speed Surface Reconstruction of Flying Birds Using Structured Light
Birds fly effectively through complex environments, and in order to understand the strategies that enable them to do so, we need to determine the shape and movement of their wings. Previous studies show that even small perturbations in wing shape have dramatic aerodynamic effects, but these shape changes have not been quantified automatically at high temporal and spatial resolutions. Hence, we developed a custom 3D surface mapping method which uses a high-speed camera to identify binary, spatially encoded striped patterns that are projected onto a flying bird. This structured light method allows automated, non-invasive 3D reconstruction of a sequence of stand-alone frames and is capable of measuring volume by simultaneously reconstructing from multiple views. We use this technique to reconstruct the 3D shape of the dorsal surface of a parrotlet wing during flapping flight at 3200 fps. From this shape we can analyze key parameters such as wing twist and angle of attack. While this novel system is designed to quantify bird wing shape and motion, it is adaptable for tracking other objects such as quickly deforming animals, especially those which are difficult to reconstruct using other 3D tracking methods.

P2.140 DEFINO, R*; SPRAYBERRY, J; DILLON, M; Muhlenberg College, University of Wyoming; *rd247297@gmail.com*
Flowering Phenology in Subalpine Meadows of Grand Teton National Park
Adequate numbers of flowering plants are essential for the health of pollinator populations - bumblebees are no exception to this phenomenon. Temperature changes due to climate change have resulted in documented instances of phenological shifts in both flowering plants and in bumblebee emergence. Interestingly, phenological shifts do not necessarily operate on the same temporal and spacial scale across species within an ecosystem. This creates the possibility of phenological mismatch - in which bumblebee populations attempt to forage at times when flower density is low. The impacts of phenological mismatches may be exacerbated in high-elevation alpine systems, which have shorter growing and foraging seasons. For example, if spring- and summer-flowering plants don't experience phenological shifts on the same time scale, bumblebees could encounter a resource gap. We monitored both flowering phenology (through marked plots) and bumblebee activity (through vane traps and plot observations) in Grand Teton National Park from late May to early June. We tracked spring phenology of 35 different flowering plant species and identified six species of queens foraging locally. Forager density was low throughout the majority of the study. These data will facilitate long-term studies of phenological mismatch in alpine ecosystems.

45.3 DELANEY, DM*; WARNER, DA; Iowa State University, Auburn University; *dmdelane@iastate.edu*
Density of Adult Lizards (Anolis sagrei) and Time of Day Influence How Juveniles Orient Themselves on Perches
Adult animals can influence the behavior of juveniles in many different ways (e.g., through parental care, competition, risk of cannibalism). Although research has suggested some juvenile behaviors are influenced by competition between age classes, few are experimental, and thus, cannot unambiguously identify causal factors that generate variation in juvenile behavior. In addition, whereas competition influences many traits, it is unclear how competition might influence how individuals orient themselves in their environment (i.e., the direction an animal chooses to face), which may be important for prey and predator detection and thermoregulation. To determine if threats invoked by competitors/predators influence orientation of juveniles, we altered the density of adult male *Anolis sagrei* in mesh enclosures to examine how juveniles position themselves in their environment. We found that juveniles decreased horizontal orientation when an adult male was present, and did so more rapidly, and increased upward orientation, when three adult males were present. Given that adult *A. sagrei* are competitors with and predators of juveniles, these changes in orientation may reduce juvenile vulnerability and increase their ability to monitor adult behavior. In addition, juveniles increased upward orientation and decreased downward orientation at night compared to daytime observations. Interestingly, juveniles also strongly shifted to face the trunks of trees at night when perched on branches. These findings provide novel insight into the factors that influence how animals position themselves within their environment.

34.6 DELIA, J*; WARKENTIN, KM; DELIA, Jesse; Boston University; *jdelia82@gmail.com*
The evolution of parent-embryo interactions in glassfrogs
The evolution of family life is shaped by complex interactions between parents and offspring. Interactions may appear harmonious, but parent and offspring interests can differ. This conflict may generate co-evolution between the traits parent and offspring use to navigate and exploit parental investment. Our research examines how interactions between sexes and life-stages impact parent and embryo evolution in Neotropical glassfrogs. Parental care was considered rare and male-biased in this family. In field observations of 38 species, we found care is ubiquitous and sex-roles vary. Comparative analyses suggest male-only care evolved repeatedly from female-only care, in association with increased care durations. Parent-removal experiments in 8 species reveal that care functions to protect embryos from dehydration and predation. Removal experiments in 6 species reveal embryos hatch early to escape abandoned eggs and extend development *in ovo* under prolonged care. Comparative analyses indicate evolutionary changes in the magnitude of hatching plasticity are associated with changes in care duration across species. We manipulated male mating-rates in two lineages with independent origins of male care to test how social dynamics affect paternal and embryo behavior. Males that mated more cared for eggs longer, and embryos delayed hatching. Prolonged embryonic development resulted in more developed hatchlings which were better at escaping from larval predators. However, extending care periods cost fathers, extending non-breeding periods and lowering mating success. This reveals father-embryo conflict over optimum care periods. Hatching plasticity allows these embryos to exploit changes in paternal investment influenced by female mating patterns. More broadly, embryo strategies are evolving in association with parental care across species.

S1.5 DELONG, John/P*; GIBERT, Jean/P; LUHRING, Tom/M; BACHMAN, Gwendolyn; REED, Benjamin; NEYER, Abigail; MONTOOTH, Kristi/M; University of Nebraska - Lincoln; *jpdelong@unl.edu*
The combined effects of reactant kinetics and enzyme stability explain the temperature dependence of metabolic rates
A mechanistic understanding of the response of metabolic rate to temperature is essential for understanding thermal ecology and metabolic adaptation. While the Arrhenius equation has been used to describe the effects of temperature on reaction rates and metabolic traits, it does not adequately describe two aspects of the thermal performance curve (TPC) for metabolic rate - that metabolic rate is a unimodal function of temperature often with maximal values in the biologically relevant temperature range and that activation energies are temperature dependent. Here we show that the temperature dependence of metabolic rate in ectotherms is well described by an enzyme-assisted Arrhenius (EAAR) model that accounts for the temperature-dependent contribution of enzymes to decreasing the activation energy required for reactions to occur. The model is mechanistically derived using the thermodynamic rules that govern protein stability and yields biologically meaningful parameters. By fitting the model to available datasets we demonstrate its utility in generating predictions about how metabolic rates acclimate and adapt to changes in thermal environment.

86.2 DEMARTINI, DG*; WAITE, JH; University of California, Santa Barbara; *demartini@lifesci.ucsb.edu*
NGS Insights into Marine Mussel Wet Adhesion
The phenomenal adaptation of marine mussels to rapidly deposit permanent holdfasts on a wide range of substrates has been explored for decades and is the epicenter of bio-inspired wet adhesion. Mussels use their specialized foot to synthesize and secrete multiple adhesive and structural proteins that self-assemble to create load-bearing structures. Each structure emanates from a central stem and consists of a collagenous, energy dissipative thread and terminates with a spatulate adhesive plaque bound to the substrate, all of which is covered by a wear-resistant biological varnish. The conglomerate of plaques, threads and stem is collectively referred to as the byssus. Years of biochemical investigation has characterized many major protein components of the byssus and deduced their functional contribution. We used de novo transcriptomics (RNA-seq) to profile specific secretory glands, and have discovered many new and highly abundant mussel foot protein genes that likely play essential roles in the mechanical performance of this biomaterial. This expanded view of the suite of mussel foot proteins bolsters emergent themes in biological adhesion and greatly expands our view of the proteins that make up the heroic byssus.

S3.7 DEMAS, G.E.*; CARLTON, E.D.; Indiana University; *gdemas@indiana.edu*
You Make Me Sick: Energetic Signals Regulating Seasonal Sickness Responses
To ensure survival and reproductive success, animals must optimally allocate energy among a wide range of costly physiological and behavioral processes while inhabiting environments that change predictably across and unpredictably within seasons. We examined the mechanisms by which seasonally-breeding rodents allocate energy between reproductive and immune systems and modulates the intensity of sickness responses to a simulated infection across seasons. Siberian hamsters inhibit reproduction and display lower body masses, lower levels of the adipose hormone leptin, and less intense sickness when housed in short, winter-like days compared to long, summer-like days. Using a range of techniques, we determined the role of energy in reproductive-immune trade-offs and seasonal regulation of sickness intensity. We examined energetic mechanisms involved in regulating reproductive-immune trade-offs in reproductively active female hamsters and show that glucose deprivation results in reproductive suppression, however suppression can be alleviated when animals ware provided with a hormonal signal of increased fat stores. Alternatively, reproduction is not inhibited when animals experience more severe glucose deprivation. We also examined the contributions of seasonal changes in energetic fuels and signals to seasonal variation in sickness intensity and show that seasonal variation in sickness-induced hypothermia is regulated by seasonal changes in glucose availability and leptin levels. Lastly, changes in insulin have both suppressive and enhancing effects on sickness intensity, depending on energetic context. Collectively, the results of these findings illustrate that physiological trade-offs and sickness intensity are sensitive to a variety of energetic modulators and that the effects of these modulators are dependent on their interactions with each other and the environment.

P2.101 DEMORANVILLE, KJ*; BOHANNON, K; CARTER, W; DOUGLAS, L; PIERCE, B; MCWILLIAMS, SR; University of Rhode Island, Sacred Heart University; *kjdemoranville@uri.edu*

Oxidative status in the European starling in response to the manipulation of dietary fatty acids, dietary antioxidants, and exercise

A high metabolic output is necessary for birds to complete long distance flights, however this high metabolism produces reactive oxygen species that have the potential to cause oxidative damage to cells and tissues if unmediated. We investigated how the oxidative defense system responded to dietary fatty acid composition and antioxidant supplementation as well as to exercise. European starlings *(Sturnus vulgaris)* were flown in a wind tunnel for on average 15 hours over 15 days. Trained birds (and paired sedentary birds) were fed one of four diets composed of either a high or low polyunsaturated fatty acid (PUFA, 18:2n-6) and a high or low concentration of the antioxidant, anthocyanin. Endurance training stressed the antioxidant defense system, as plasma oxidative capacity (Oxy-adsorbant test) was lowest in exercised birds during training immediately before and after a 3 hour experimental flight compared to pre-training and at sacrifice 2 days post-training ($p<0.05$, RMANOVA). Oxy did not change among sedentary birds ($p=0.19$) nor in accordance with diets (neither in controls $p=0.83$ nor trained birds $p=0.13$). Plasma oxidative damage (dROMs test) was unchanged in sedentary birds ($p=0.50$), however damage was highest in trained birds immediately before a 3 hour flight compared to post-flight and pre-training ($p<0.05$). Red blood cell glutathione peroxidase activity was greater in all trained diet groups (from 13-26%) immediately post-flight with the greatest enzyme activity in the high antioxidant groups. The antioxidant defense system demonstrates flexibility in response to elements important during migration, notably exercise and nutrition.

94.2 DEORA, T*; VARDHAN, A; NAIK, S; GHOSH, A; GUNDIAH, N; SANE, SP; National Centre for Biological Sciences, Bangalore, India and University of Washington, Seattle, National Centre for Biological Sciences, Bangalore, India, National Centre for Biological Sciences, Bangalore, India and Department of Mechanical Engineering, Indian Institute of Science, Bangalore, India and University of California, Berkeley, Department of Mechanical Engineering, Indian Institute of Science, Bangalore, India; *tanvid2@uw.edu*

Mechanics of the Wing Hinge in Flies

The evolutionary trend towards miniaturization of body size imposes huge constraints on insect flight. Smaller insects typically flap their wings at high frequencies to stay in air, and require powerful, fast-acting muscles to control their rapid wing movement. Dipteran, Hymenopteran and Coleopteran insects have evolved specialized myogenic muscles that power high frequency wing motion. These muscles cause thoracic vibrations, which are translated via a complex wing hinge into wing motion. In Diptera, passive mechanical linkages embedded within the thorax precisely coordinate the motion of the two wings as well as of each wing relative to the ipsilateral haltere, ensuring robust wing-haltere coordination despite changes in wingbeat frequency due to natural wear-and-tear of wings. Moreover, each wing can be unilaterally controlled by a putative clutch mechanism at the wing base. A set of approximately 18-19 neurogenic muscles underlying the wing hinge provide fine control of wing kinematics and orchestrate rapid maneuvers. To understand the mechanical basis of the clutch, we imaged the musculo-cuticular architecture of the wing hinge using X-ray micro-tomography in Sarcophagid flies. Using this technique, we can determine the relative configuration of various sclerites of the wing hinge under different wing configurations. We will describe the initial results from our studies to understand the clutch mechanism in flies.

P2.79 DERRICKSON, EM; Loyola University Maryland; *ederrickson@loyola.edu*

The Relationship Between Seasonality and Growth Rate Within the Rodentia

Cessation of breeding is characteristic of small mammals inhabiting areas that are seasonally cold or seasonally hot and arid. The reasons for cessation include lack of food or water to sustain reproduction or the competing costs of thermoregulation and reproduction. The impact of seasonality on breeding could affect several life history characteristics including adult body mass, growth rate, age at first reproduction, juvenile survivorship and rate of development. In this study, I compared the relationship between seasonality on rate of growth to weaning mass, mass at first reproduction and adult mass to determine if growth rate increases as the length of the favorable season for reproduction decreases. In a sample of non-hibernating rodents, larger species were significantly more likely to be classified as year-round breeders than smaller ones were. When the effect of adult body mass was held constant, the rate of attaining adult body mass was inversely related to the length of the breeding season. However, juvenile growth from birth to weaning and rate of attaining age at first reproduction were not significantly related to season length. Additionally, it appears that rapid growth in shorter habitats occurs concurrently with a decrease in neonatal development and an increase in litter size. Further work is needed to identify whether size-based overwinter adult mortality is the primary selection pressure selecting for faster growth in more seasonal habitats.

S3.5 DEVICHE, P.J.*; BITTNER, S.; GAO, S.; VALLE, S.; Arizona State University; *deviche@asu.edu*

Food Supply and the Timing of Reproduction

The timing of reproduction generally is a critical component of fitness and is related to trophic resources. Ultimately, reproduction is often synchronized with periods of peak food resources for the young, thus benefiting offspring development. Proximately, breeding when these resources are most abundant helps individuals sustain the energetic costs that are associated with expression of reproductive behavior and physiology. Studies manipulating food availability demonstrate the importance of this factor on reproduction, but the physiological and in particular neuroendocrine mechanisms that mediate effects of food availability on the non-mammalian vertebrate hypothalamic-pituitary-gonadal (HPG) axis are poorly understood. These mechanisms may involve a direct role for metabolites (e.g., glucose and fatty acids) related to the energetic state on the HPG axis, in particular the hypothalamus and gonads. Alternatively, or in addition, these mechanisms may be indirect and due to actions of hormones (e.g., leptin and glucocorticoids [GC]) whose secretion responds to the energetic state. Supporting this view, GC secretion often increases during homeostatic challenges such as food restriction. Furthermore, when energy resources are limited, GC can facilitate the organism's transition from reproductive condition to self-maintenance. A main challenge in determining whether the HPG axis activity is directly or indirectly regulated by energetic signals is that the secretion of hormones such as GC is often affected by homeostatic challenges, but these hormones can in turn profoundly affect an organism's metabolic state. In this talk we will discuss how food availability influences reproductive physiology and the metabolites, hormones, and neuroendocrine pathways that potentially mediate this influence.

49.2 DEVRIES, MS*; RAZA, A; WEBB, SJ; TAYLOR, JRA; Scripps Institution of Oceanography, UC San Diego; *mdevries@ucsd.edu*

Is smashing always a success? How a smashing mantis shrimp consumes both hard-shelled and soft-bodied prey

Smashing mantis shrimp use their powerful, hammer-like raptorial appendages to break open hard-shelled prey, yet one species, *Neogonodactylus bredini*, also consumes soft-bodied, evasive prey. Given that the appendage is specialized for striking with great force, which is required for consuming hard-shelled but not soft-bodied prey, we hypothesized that *N. bredini* uses different feeding strategies to consume these distinct prey types. We compared the feeding behaviors that *N. bredini* individuals use to consume hard-shelled clams and evasive grass shrimp by analyzing real-time and high-speed videos of prey capture events. We found that mantis shrimp manipulated clams with their maxillipeds before striking the clams on average 21 times (17 s.d.) (1-55 strikes per individual, 55 individuals) with a mean duration of 0.8 ± 0.3 ms (1-6 strikes per individual, 17 individuals). Strike duration scaled positively with carapace length: $R^2 = 0.6$, $p < 0.001$). When consuming grass shrimp, *N. bredini* lunged forward and grabbed prey with their maxillipeds. Grab duration was 75.5 ± 34.0 ms (1-10 grabs per individual, 15 individuals), which did not scale with carapace length ($R^2 = 0.1$, $p = 0.1$). Six individuals opened the dactyl segment of the appendage to impale grass shrimp during a strike. These strikes were longer in duration than those used to break clams (2.7 ± 2.1; 1-5 strikes per individual), likely because open dactyls increase drag. Overall, we found two distinct feeding behaviors used by *N. bredini*: appendage strikes and grabs with maxillipeds. Given that *N. bredini* is known to be a generalist predator, our findings suggest that individuals do not solely rely on their powerful smashing strikes, but instead have a repertoire of behaviors that aid in consuming a diversity of prey.

76.3 DI SANTO, V*; KENALEY, CP; LAUDER, GV; Harvard University, Cambridge, MA, Boston College, MA; *vdisanto@fas.harvard.edu*

A Non-Linear Relationship between Swimming Metabolism and Speed in a Negatively Buoyant Batoid Fish

Swimming performance is considered a key trait determining the ability of a fish to find food, refugia, and mates, and to avoid unfavorable conditions and escape predators. Typically, metabolic rates increase with speed up to a critical point: the critical swimming speed at which fish fatigue. At the same time, fish must stabilize their body posture at very low speed and thereby incur high energetic costs. The combination of high metabolic costs at extreme speeds and relatively-lower costs at an intermediate cruising speed, may result in a non-linear metabolic-speed relationship. However, to date there are no complete data sets to confirm this hypothesis. In this study we quantified the metabolic costs associated with varying speed (0.75-2.25 BL $\times$ s^{-1}) in a negatively buoyant fish, the clearnose skate *Raja eglanteria*. We employed two approaches, a classic critical swimming speed protocol and a single-speed exercise and recovery procedure. We found a discrepancy in the metabolic-speed relationships using the two methods: when using the critical swimming protocol, metabolic rates increased with speed, but the single-speeds approach showed a J-shaped aerobic metabolic-speed relationship and an anaerobic component at each velocity tested. When the anaerobic portion was added to the aerobic costs of locomotion, the energetic curve resembled that quantified using the critical swimming speed protocol. These results suggest that anaerobic metabolism is involved during low as well as high swimming speeds in the clearnose skate and that critical swimming protocols might misrepresent true costs of locomotion across speeds in negatively buoyant fishes.

83.1 DIAL, K P; Univ. Montana, Missoula; *kdial@mso.umt.edu*

Waxing and waning of wings during molt, growth, and secondary loss of flight in birds.

Locomotor behavior and wing use among transitional forms of birds has only recently been evaluated. Recruitment of rudimentary and/or compromised wings appears common among extant species during: (1) ontogeny (development of wings), (2) molting (seasonal loss and regeneration of feathers), (3) maturation (increase in body mass relative to constant wing size) and (4) flight degradation (semi-flightlessness, triggered by reduction of predation pressure). Therefore, all birds undergo transitional anatomical changes that result in the reduction and/or augmentation of wing use. I survey most avian extant clades to better understand how species employ rudimentary wings during locomotion. In some cases, juveniles are more flight-capable than the adults (e.g., Giant coot and Brush Turkey) resulting from significant changes in wing loading during maturation. During changes in wing development (1-4 above), birds recruit their transitional wings, be it for coordination/balance or locomotion, by flapping their forelimbs rather than glide. Avian clades that invest heavily in their hindlimb apparatus (e.g., Galliformes, Anseriforms, etc.,) appear predisposed to lose flight if released from predation pressure but only if they can acquire food year-round without flight. Whereas, avian species that heavily invest in their forelimbs at the expense of hindlimbs (e.g., Apodiformes), have not been observed to evolve semi-flightless or flightless forms. An overarching trend among extant avian species during the waxing and waning of wings is flapping behavior (not gliding) and the simultaneous recruitment of hindlimbs to assist transitional wings.

60.1 DIAL, TR*; BRAINERD, EL; Brown University; *terry_dial@brown.edu*

Effects of Feeding Performance on the Limits of Guppy Offspring Size

Offspring size is a key life history trait that varies widely and affects the function of neonatal forms within their immediate environment. Using the Trinidadian guppy (*Poecilia reticulata*) as a model we ask, why do the smallest offspring reach a lower limit of size (5.5 mm SL) in high predation (HP) environments and why do the largest offspring reach an upper size limit (7.5 mm standard length, SL) in low predation (LP), high competition environments? We predict that the lower limit of size runs up against hydrodynamic limitations, whereas the upper limit is set by diminishing returns on improved feeding performance at larger sizes. We employ viscosity manipulations to examine the effects of hydrodynamics during suction feeding, and measured jaw kinematics during scrape feeding on an encrusting substrate across a size range of guppy offspring. We find that hydrodynamics do not constrain feeding rate and suction generation at small size, but that across treatments performance varied as a function of both size and maturity. Over the size range examined, guppy neonates varied four-fold in their degree of morphological maturation (20% ossification in HP; 80% ossification in LP). During scrape feeding, rotation at the intramandibular joint doubled among guppy offspring, ranging from 11.7° in HP to 22.9° in LP neonates. The finding that neonatal guppy offspring covary in both size and maturity at birth means that being smaller also means being less mature, which amplifies the negative performance effects of being born small. These findings also indicate that degree of maturity begins to plateau in larger offspring, which could reduce selection for even larger offspring in LP environments, if maturity is the main driver of scrape feeding performance.

S1.7 DIAMOND, SE*; CHICK, L; DUNN, RR; ELLISON, AM; SANDERS, NJ; GOTELLI, NJ; Case Western Reserve Univ., North Carolina State Univ., Harvard Forest, Center for Macroecology, Evolution and Climate, Univ. of Vermont; *sarah.diamond@case.edu*

Heat tolerance predicts the strength of species interaction effects under global climate change

Evidence for the relative importance of direct effects of climate change and indirect effects mediated thorough species interactions is limited. Among these limited studies, there is contrasting support for stronger direct versus indirect effects of changes in climate on communities. Trait-based approaches aimed at explaining such variation in responses to climate change have met with considerable success. The question then is whether we can use trait-based approaches to predict when direct effects of temperature rise or indirect effects of altered species interactions are likely to dominate responses to climate change. Thermal tolerance traits might inform when species interactions are likely to be important, as only subsets of communities will be able to use the available warmer climatic niches and competition intensifies in the remaining cooler climatic niches. Here we explore the relative roles of the direct effects of temperature change and indirect effects of species interactions on forest ant communities warmed as part of a large scale climate manipulation at high and low latitude sites in eastern North America. We found overall mixed support for the importance of species interactions, but found that the magnitude of these interaction effects was predictable based on the upper thermal tolerance of the focal species. Forager abundance and nest site occupancy of heat intolerant species was more often influenced by interactions with other species than by direct effects of temperature. Our findings suggest that thermal tolerance may be used as a general guide for when species interactions will be more likely to influence responses to global climate change.

12.3 DIAMOND, KM*; SCHOENFUSS, HL; WALKER, JA; BLOB, RW; DIAMOND, Kelly; Clemson Univ., St. Cloud State Univ, Univ. of Southern Maine, Clemson Univ; *kmdiamo@clemson.edu*

Does ontogenetic environment influence escape response? Comparative escape responses of goby fishes through ontogeny and among islands

Gobies living in oceanic island streams vary dramatically in their patterns of exposure to aquatic predators, both through stages of ontogeny and across species. Following an oceanic larval phase, juveniles of all species arrive in lower stream reaches rich in piscivore predators. On the Island of Hawai'i, some species (*Sicyopterus stimpsoni*, *Awaous stamineus*) climb waterfalls to escape the reach of non-climbing predators, but others (*Stenogobius hawaiiensis*) live their entire lives in predator infested waters. In other island systems, such as La Réunion in the Indian Ocean, climbing gobies (*Sicyopterus lagocephalus*, *Cotylopus acutipinnis*) and their potential predators, especially freshwater eels, are present from estuaries to upper reaches. We sought to test how escape performance changed between juveniles and adults of species that did (*S. stimpsoni*) or did not (*S. lagocephalus* and *C. acutipinnis*) escape the predator range, and how escapes varied across adults of species with different degrees of predator exposure. We collected 493 escape response trials among five species using an observation tank and water pulse stimulus, and found differences in escape response both through ontogeny and across species. Juveniles respond more frequently than adults across all species. However, adults from Hawaiian species show higher response frequencies than those from La Réunion, especially when attacks are from caudal and lateral directions. These results show a complex association between exposure to predation selection and escape performance.

116.6 DIAMOND, SE; CHICK, L; PEREZ, A; STRICKLER, SA; MARTIN, RA*; Case Western Reserve University; *ram225@case.edu*

Rapid evolution of ant thermal tolerance within an urban heat island

Worldwide, the spread of urbanization is accelerating. Increases in temperature associated with urban heat island effects provide an ecological imperative and a unique opportunity to explore the evolutionary mechanisms that underlie organismal responses to rapid environmental change. We used the acorn ant, *Temnothorax curvispinosus*, to compare shifts in thermal tolerance of ants from rural and urban habitats throughout Cleveland, USA. Urban warming in the region has been ongoing for the past century, which translates to 20 or fewer acorn ant generations. Using a common garden design, we found that upper and lower thermal tolerances assessed with a fast rate of temperature increase (1 °C min-1), were both higher for ants from urban source populations. Owing to the asymmetry in the magnitude of shifts in upper versus lower tolerances, tolerance breadth decreased in urban habitats. Mechanistically, these shifts in thermal tolerance under urbanization reflected both evolutionary change and phenotypic plasticity, as ants from urban areas exhibited higher thermal tolerances compared with ants from rural areas regardless of rearing temperature, and ants reared in the warmer temperature treatment exhibited higher tolerances than ants reared in the cooler temperature treatment. We also found evidence of evolved plasticity as the slope of the response to warmer and colder rearing environments differed significantly among rural and urban populations. Our study provides evidence of rapid evolution of thermal tolerances, and suggests the importance of including evolutionary responses for understanding and forecasting organismal responses to climatic change.

P3.225 DIAZ CRUZ, K*; ASTLEY, HC; MENDELSON, JR; GOLDMAN, DI; University of Puerto Rico, Puerto Rico, University of Akron, Ohio, Zoo Atlanta, Atlanta GA, Georgia Institute of Technology, Atlanta GA; *kdiaz.022@gmail.com*

Undulation on granular media: a robophysical investigation

Snakes exhibit effective limbless locomotion in a diversity of terrains, and many species excel at moving across granular media, a complex and yielding substrate that exhibits both solid and fluid-like behavior. In a previous study, the locomotion of 30 species of snakes, including 18 species of pit vipers, was examined on a granular medium (Marvi et al 2013 Science). While other taxa all moved effectively on level sand (regardless of native habitat type) and most moved effectively on 10 and 20 degree inclined sand (max angle of stability = 28 degrees), 25% of the pit vipers produced minimal displacement on horizontal sand, and almost all failed on inclined sand. To understand the role of interactions between the body surface and the granular media in determining success or failure of snakes on granular media, we performed systematic locomotor experiments using a robot snake using different undulation strategies at various inclines, which allowed for precise control of friction and undulation strategy. The robot consisted of ten servomotors in 3D-printed shells oscillating in a sine wave with a maximum bend angle, with each motor having a phase offset relative to the prior. High overall skin friction resulted in minimal displacement, whereas, with low friction, success was dependent on the angle between joints and the number of waves on the body. Decreasing the ratio of parallel and perpendicular forces via a ventral ridge improved performance across most undulation strategies. This suggests an important influence of body surface on limbless locomotion through granular media, and highlights the importance of the interaction between snake skins and granular media.

136.3 DICKERSON, BH*; DICKINSON, MH; California Institute of Technology; *bdicker@caltech.edu*

Drosophila haltere steering muscles are active during voluntary maneuvers and are directionally tuned.

As flies navigate their environment in search of food or mates, they execute sharp turns known as saccades that occur faster than the blink of a human eye. These maneuvers are initiated by changes in visual motion detected by the eyes, whereas their termination is under the control of small, dumbbell-shaped structures called halteres. The halteres are located behind the forewings and evolved from the hindwings. These structures oscillate during flight and function as biological gyroscopes; they detect unexpected body rotations during flight and trigger wing reflex maneuvers. Like the wings, the halteres possess a small set of muscles that control the structure's motion from their base and receive input from the visual system. However, while the critical role of the halteres in stabilizing flight is long known as flies crash catastrophically without them, the role of the haltere and its steering muscles during flight maneuvers remains unclear. Using fluorescence imaging of the genetically encoded calcium sensor GCaMP6f, we observed haltere steering muscle activity in the fruit fly, *Drosophila melanogaster*, during a broad array of visual stimuli. We found that these muscles are particularly responsive during voluntary escape maneuvers and are tuned to rotations about the body's cardinal axes. These results suggest that the visual system is able to activate individual muscles to control haltere motion, and thus mechanosensory input. With this work, we are beginning to understand how hard-wired reflexes may be modified by the nervous system to produce voluntary behaviors.

P1.219 DICKERSON, D; MAIE, T*; Lynchburg College; *maie.t@lynchburg.edu*

Evaluation of correlation between material properties of the vertebrae and predator escape performance in yellow perch, Perca flavescens

Anatomy and functional design of organisms often exhibit strong correlation with how effectively and efficiently certain biological tasks are performed. Our study is conducted to test the hypothesis about the relationship between structural integrity of the vertebrae in the spine and their contribution to the functional performance of the spine in fishes. Using a material testing system, a series of force-bearing capacities of the vertebrae from different locations of the spine in yellow perch (*Perca flavescens*) was tested. The strength of vertebrae was equal for all the vertebrae tested. Young's modulus was approximately 20% higher for the vertebrae from the caudal peduncle region than the vertebrae from other body regions. Using a highspeed videography, kinematics of the body during the predator evasion (C-start) behavior was analyzed and cross-referenced with the material property data of the vertebrae. We discuss the implication of our results for the pattern of propulsive force production through the body of the fish, as well as locomotor function and performance of fishes in different environmental contexts; more specifically, the impact of different mineral bioavailability as well as mining-related pollution on the functional morphology and survival of the fish.

P3.184 DICKSON, K.*; MALIK, A; KITAGAWA, T; FUJIOKA, K; SCHULLER, K; California State Univ. Fullerton, Flinders Univ., Adelaide, South Australia, Univ. Tokyo, Kashiwa, Japan, National Research Institute of Far Seas Fisheries, Shizuoka, Japan; *kdickson@fullerton.edu*

The Transition to Regional Endothermy in Pacific Bluefin Tuna, Thunnus orientalis

In Pacific bluefin tuna, vascular counter-current heat exchangers (retia) conserve metabolic heat, allowing aerobic (red) locomotor muscle temperature to be elevated above water temperature. We investigated molecular controls involved in the transition to regional endothermy in year 0 bluefin (20 cm fork length). Temperatures, activity of the mitochondrial enzymes citrate synthase (CS) and cytochrome *c* oxidase (COX), and gene expression for CS and COX1 and for peroxisome proliferator-activated receptor-γ coactivator (PGC-1α) were quantified in red and white muscle. 20-cm bluefin cannot elevate tissue temperatures significantly, but possess small red muscle retia and internalized red muscle with aerobic enzyme activities similar to those of larger, endothermic individuals. CS and COX activities per gram tissue were 6.2- and 10.4-fold higher in red compared with white muscle, indicating that mitochondria are more abundant in red muscle, as expected. We hypothesized that this would be due to increased transcription of the genes encoding those enzymes and the master regulator of mitochondrial biogenesis PGC-1α. CS, COX, and PGC-1α transcript abundances normalized to β-actin transcript abundance did not differ significantly between the two muscle types but, when normalized to the amount of RNA, CS, COX, and PGC-1α transcripts were 3.0-, 2.0- and 4.3-fold more abundant in red versus white muscle. Post-transcriptional regulation of CS and COX gene expression may also be involved because the fold-differences in enzyme activity were greater than those in gene expression. Results should inform aquaculture and conservation programs for bluefin tunas.

57.5 DIDION, JE*; LAYNE, JE; University of Cincinnati, Cincinnati, OH; *didionje@mail.uc.edu*

Behaviorally assessing the spectral sensitivity of the Atlantic sand fiddler crab, Uca pugilator

Vision is the primary sensory channel for numerous species and represents a key selective advantage throughout evolution. Many species have evolved the ability to perceive colors, and for many of these, color perception has become crucial in intra-species communication by relaying information to conspecifics about species, sex, reproductive state, defensive abilities, size, health, and social status. The Atlantic sand fiddler crab, *Uca pugilator*, is an excellent system in which to study the evolution and the importance of color signaling because many of their social interactions and individual activities rely on their visual system including burrow surveillance, predator avoidance, and mate attraction. During courtship, males visually attract attention by performing their stereotypical claw-waving displays and potentially using their carapace, leg and claw coloration as additional signals. This study aimed at assessing the potential contribution of color sensitivity to intraspecific signaling by measuring the spectral sensitivity of this species using a looming stimulus (i.e. expanding disc), which elicits an escape response in the crabs. By manipulating the wavelength and intensity of the looming stimulus, the spectral sensitivities of the crabs were assessed. This study found that the crabs are sensitive to wavelengths ranging from 360nm to 640nm, and are most sensitive near 490nm. There is a drastic decline in sensitivity to wavelengths longer than 590nm. These results coincide with the peak sensitivities (~480nm) predicted from Uca pugilator's opsin gene sequence.

P1.41 DIMEO, CM*; PROVENCHER, C; PLACHETZKI, D; Univeristy of New Hampshire; *cmd2012@wildcats.unh.edu*

Phototactic Preference and its Genetic Basis in the Planulae of the Colonial Hydrozoan Hydractinia symbiolongicarpus

Sessile marine invertebrate larvae commonly possess motile larval stages that make settlement decisions based on environmental sensory cues. Phototaxis, mobility toward or away from light, is a common feature of marine larvae for a diversity of taxa, but the behavioral and genetic details are only known from a few systems. Here we describe results from a study of wavelength sensitivity, preference and gene expression during the development of the colonial hydrozoan *Hydractinia symbiolongicarpus*. We monitored positive phototaxis to pure Red, Blue and Green light over the course of development and performed RNAseq experiments for selected developmental time points. We find that *Hydractinia* larvae are strongly phototactic to green light after the development of the sensory furrow upon larval day two of development and remain so until settlement. We find a significant, but weak response to pure blue light and no significant phototaxis response to red light. Analysis of RNAseq data taken from before and after the onset of phototaxis reveals a set of differentially expressed genes that are putatively involved in this photo response.

P1.239 DING, Y*; MING, TY; GOLDMAN, DI; Beijing Computational Science Research Center, Georgia Institute of Technology; *dingyang@csrc.ac.cn*

Transition of torque pattern in undulatory locomotion due to wave number variation

In undulatory locomotion, torques (bending moment) are required along the body to overcome the external forces from environments and internal body forces. For animals such as eels, such torques are generated by muscles and therefore have been used to explain the timing of muscle activation. Previous observations of muscle activation and torques from models all showed a single traveling wave pattern from head to tail. However, previous studies are limited to animals or models with wave number (number of wavelengths on the locomotor's body) less than 2. Using a resistive force theory model, we find that as the wave number increases from 0.5 to 1.8, the speed of the traveling wave of torque decreases, and when the wave number increases to 2 and greater, the torque pattern transits from a single traveling wave to two traveling waves and then a complex pattern that consists two wave-like patterns. By analyzing the contributions of forces along the body to the torques, we explain the speed decrease of the torque wave and the pattern transition. Our results give insights into the mechanics of undulatory locomotion and predict possible muscle activation patterns that have not been observed in animals.

P3.255 DINGWALL, HL*; GRINSTEIN, M; CAPELLINI, TD; GALLOWAY, JL; Harvard U., Mass. Gen. Hospital; *hdingwall@fas.harvard.edu*

Transcriptional changes during early postnatal tendon growth

Tendons not only transmit muscular forces to the bones on which they insert, but their viscoelastic properties also contribute to energy savings during locomotion. It is well-known that a tendon's dimensions directly influence its spring-like behavior, but the mechanisms that control adult tendon size are poorly understood. Although some tendon growth occurs prenatally, driven largely by cell proliferation, a substantial amount of growth occurs postnatally. Recent studies have shown that postnatal growth in mouse tendon is governed by expansion of the ECM. Additionally, it has been demonstrated that cell turnover rates in neonatal tendon are substantially higher than adult tendon, in which many cells are post-mitotic. We sought to gain a more detailed understanding of when tendon cell proliferation rates decrease during the early postnatal period and which molecular mechanisms control this change in proliferative activity. Using BrdU pulse labeling to quantify cell turnover in mouse limb tendons, we found that proliferation is relatively high in the early postnatal period (postnatal day (P)0-P14), but drops by P21 and remains low into early adulthood (P35). Our RT-qPCR screen found relative expression changes for several genes involved in the Hippo pathway, which is known to regulate cell proliferation and tissue growth. Specifically, we found that *Yap*, a downstream effector of this pathway, is upregulated at P7 relative to P0, while two known targets of YAP are upregulated later at P14. Expression of the pro-collagen gene *Col1a2* was also highest at P14 suggesting that ECM production becomes an important component of tendon growth at this time. We are currently working to place these findings in a broader transcriptomic context to improve our understanding of the molecular control of tendon growth and the evolution of tendon size.

19.5 DIRENZO, GV*; ZIPKIN, EF; GRANT, EHC; LONGO, AV; ZAMUDIO, KR; ROYLE, JA; LIPS, KR; Michigan State University, USGS Patuxent Wildlife Research Center, University of Maryland, Cornell University, USGS Patuxent Wildlife Research Center; *grace.direnzo@gmail.com*

Modeling amphibian-chytrid disease dynamics less than 10 years following a chytrid outbreak

As fungal diseases spread globally, the lack of host persistence after outbreaks imperils biodiversity. In the case of the amphibian-killing fungus Batrachochytrium dendrobatidis (Bd), invasions cause rapid mass mortality in hosts. Typically, a small proportion of species and individuals persist alongside Bd following outbreaks and it remains unclear how. To explain host-pathogen persistence, we test the following hypotheses: source-sink dynamics, rescue hypothesis, and environmental hotspots. Using a novel disease-structured generalized N-mixture model, we quantified host demographic processes from a Neotropical amphibian community. Our results present a case for the rescue hypothesis, where low pathogen-induced mortality, stable host abundance, moderate Bd prevalence, and low infection intensities, suggest that hosts have adapted to Bd infection. This type of host-pathogen persistence challenges reintroduction programs of endangered species that have lost genetic variability, the raw material for adaption.

86.3 DITSCHE, P.*; SUMMERS, A.; University of Washington, University of Alaska Anchorage, University of Washington; *pditsche@alaska.edu*

Clingfish inspired suction cups - Holding tight when it gets rough

While artificial suction cups usually only attach to very smooth surfaces, Northern clingfish can attach to a huge variety of surfaces ranging from very smooth to very rough. Larger specimens can attach to surfaces as rough as 0.5-1 mm grain size, which is about as rough as sandstone. Moreover, the little intertidal fish can even hold onto slimy biofilm covered surfaces. All these are abilities which are highly desirable for technical applications. In our former work we could show that the elasticity of the suction cup in combination with the hierarchical structures on the disc margin are some of the key features enabling the fish to attach to this challenging surfaces. The hierarchical structures on the disc margin consist of papillae (~150µm) covered with rods (~5µm), which are divided into tiny filaments at their tips (~0.2µm). These specialized structures enable not only a perfect adaptation to the surface irregularities of a substrate, but also increase the friction properties of the disc margin. The increased friction forces act against the forces pulling the disc margin in central direction during detachment. Therefore, the increased friction properties of the disc margin avoid or delay failure of the suction cup and result also in increased attachment forces. Transferring the principle of increased friction properties and the high adaptability of the disc margin to an artificial suction device we were able to develop a bio inspired suction cup. Our bio inspired suction cups develop tenacities of up to 70KPa on surfaces as rough as 270 m grain size (roughest surface in the experiment). On substrates of the same roughness the bio inspired suction cups attached several weeks under water in an experimental setting. Our suctions cups could be technical applied in fields such as whale tagging or surgery.

26.5 DITSCHE, P; JACKSON, P; WOOSTER, A; ASPELUND, L; TURINGAN, R; PENROD, L; DUMONT, B; FERRY, L; WILGA, C*; Univ Alaska Anchorage , Florida Inst Technology, Univ Massachusetts Amherst, Arizona State Univ; *cwilga@alaska.edu*

Biomechanical properties of the jaw and hyoid cartilage in elasmobranchs

The skeleton of sharks and rays is composed of cartilage. The jaw joint articulates with the hyomandibula while the upper jaw has one, two, or no articulations with the cranium depending on the type of jaw suspension. Squalean sharks are orbitostylic; the upper jaw is laterally restricted by the cranial-upper jaw joint. Galean sharks are hyostylic; here the mobility of the cranial-upper jaw joint is not restricted laterally. Rays are euhyostylic, the upper jaw is not connected to the cranium and has the greatest mobility. While the hyoid is intact in orbitostyly and hyostyly, it is broken up in euhyostyly. Due to the increased support from the cranium we assume that the more restricted jaw types might be less stiff than less restricted ones. Another important aspect influencing the biomechanical properties of the feeding apparatus is feeding type. To assess how these morphological and behavioral differences affect the biomechanical properties of the cartilaginous elements we compare species that vary in jaw suspension and feeding type. We measured biomechanical properties such as stiffness, strain, stress and Poisson's ratio of the jaws and hyoid elements using a mechanical testing system. We determined the strain in vivo for mouth opening and closing. In most species, the upper and lower jaws have a higher degree of mineralization compared to the hyomandibula and ceratohyal. The higher mineralization corresponds with higher stiffness in these elements. Moreover, higher stress was required to bend these elements. Correspondingly we found lower strain and less deformation in the jaw cartilages compared to the hyoid cartilages.

15.1 DIXON, GB*; BAY, LK; MATZ, MV; University of Texas, Austin, Australian Institute of Marine Science, Townsville, QLD, Australia; *grovesdixon@gmail.com*

Implasticity gene body methylation in a reef-building coral

There is currently great interest in the role of epigenetic factors in phenotypic plasticity and acclimatization. In a typical envisioned scenario, epigenetic modifications are adjusted in response to external cues resulting in gene expression change to fit environmental conditions. Thus far, however the evidence of this mechanism in invertebrates has been lacking. Here, we sought to quantify the change in gene body methylation (gbM, the predominant type of DNA methylation in invertebrates) relative to gene expression change in a reef-building coral upon transplantation to a novel environment. Twenty colonies of *Acropora millepora* were divided in half and reciprocally transplanted between reefs separated by five degrees of latitude on the Great Barrier Reef. Gene body methylation was measured using methylation-binding-domain enrichment coupled with Illumina sequencing (MBD-seq). Colony identity was the strongest predictor of gbM, despite the fact that the coral halves spent months in different environments. Despite abundant changes in gene expression (315 differentially expressed genes) we detected no differentially methylated genes in response to transplantation. In contrast, over 100 genes were differentially methylated based on corals' origin. Similarly, correlation network analysis revealed multiple clusters of epigenetically correlated genes related to origin and growth rate, but none related to transplantation. Notably, differential methylation depending on corals' origin was positively correlated with difference in gene expression among populations. We conclude that changes in gbM do not drive molecular acclimatization in A. millepora. Instead, differences in gbM between populations predict variation in gene expression that is unresponsive to environmental change.

P1.106 DIXON, GB*; MATZ, MV; University of Texas, Austin; *grovesdixon@gmail.com*

Estimating the strength of spatially varying selection in a reef-building coral

Spatially varying selection could considerably limit the effective migrant exchange among ecologically distinct locations. In instances of "phenotype-environment" mismatch, genotypes selected to survive in one environment might be unfit to live in another. Here we use genome-wide genotyping (2bRAD) to test for evidence of spatially varying selection between proximate (< 20km apart) but environmentally distinct inshore, offshore, and deep reefs. We sampled juvenile (less than 2 years old) and adult individuals of the great star coral *Montrastraea cavernosa* and examined how allele frequencies change among age cohorts in differing habitats. Although genome-wide divergence (Fst) between populations was negligible, several dozen 2bRAD markers were highly divergent and formed a single cluster of linkage disequilibrium corresponding to a genomic region >100 kB in size, which is expected under very recent or ongoing selection. Moreover, these differences were less pronounced among juveniles compared to adults, indicating that spatially varying selection is ongoing and gradually removes migrants bearing "locally wrong" genotypes. These observations confirm that M. cavernosa is strongly affected by spatially varying selection across environmental gradients in the Florida Keys, reducing effective migration among habitats and limiting the capacity of coral populations to recover from disturbances.

S1.3 DIXSON, Danielle L; University of Delaware;
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Understanding the direct effects of pH on the sensory systems of marine organisms

Ocean acidification has been identified as a major threat to marine life. In addition to reduced calcification, elevated CO2 affects the sensory systems of marine organisms. Sensory perception directly impacts essential behaviors, such as homing, settlement, predator evasion and foraging. Sensory perception of chemical, visual and auditory cues is an integral part of community dynamics in marine systems and plays an important role in the daily life and survival of marine organisms. Behavioral interactions mediated by sensory perception influence ecosystem dynamics. If ocean acidification negatively impacts sensory perception, there is the potential that it could also indirectly harm community health and structure. For this reason, it is essential to fully evaluate the potential impacts of ocean acidification on sensory perception. The current knowledge base on the effects of ocean acidification on sensory systems, specifically investigating chemoreception have identified key processes that are potentially disrupted. However, there are a number of gaps and biases in the field, which need to be rectified for a full understanding on the impact of future climate conditions. The next generation of research on this topic should amend these biases in order to gather a more thorough prediction of how the ocean organisms will respond to ocean acidification.

49.4 DOBKOWSKI, KA*; CROFTS, SB; University of Washington, New Jersey Institute of Technology; *kdobkows@uw.edu*

Material Properties of Juvenile Bull Kelp (Nereocystis luetkeana)Across an Ontogenetic Series

Bull kelp (*Nereocystis luetkeana*) are an important source of primary production and three-dimensional habitat in nearshore subtidal areas in the NE Pacific, including the Salish Sea. These kelp must be adapted to persist in in wave-swept environments subject to strong tidal currents throughout their life cycle. Previous data collected subtidally near San Juan Island indicate that juvenile mortality of bull kelp is very high. While material properties of adult bull kelp have been studied previously, less is known about those of juveniles. We used SCUBA to collect juvenile bull kelp (stipe length less than 40 cm) at several subtidal sites in the San Juan Channel and investigated material properties in the lab using a Materials Testing System (MTS). For each individual, we measured stipe length, stipe width under the bulb, stipe width above the holdfast, stipe width at the visually narrowest point, and bulb width; we also noted any damage to the stipe. We used a custom 3D printed cradle to hold the bulb and freeze-clamped the holdfast before putting the stipe under tension until failure. For each trial we recorded maximum force, force at failure, and calculated Young's Modulus. We found morphology to be an important determinant of juvenile bull kelp stipe failure and that cross-sectional area may play a role in determining where stipes fail. Additionally, juvenile bull kelp stipes showed great extensibility prior to failure. Data on the material properties of juvenile bull kelp is important to help us understand the potential causes of high juvenile bull kelp mortality and "beheaded" individuals observed in the field. Ultimately, this work will help inform future conservation, restoration, and management efforts.

P1.36 DOBROZSI,, SJ; MUNOZ, MC*; JAYNE, BC; Lees-McRae College, Banner Elk, NC, Univ. Cincinnati, OH; *bruce.jayne@uc.edu*

The Optokinetic Response and Visual Acuity of Phylogenetically Diverse Snakes

Ancestral snakes may have been fossorial and had poor vision. Furthermore, some anatomical features suggest that, after nearly being lost, the eye of snakes was re-elaborated. However, experimental data are so sparse that the variation in visual acuity and its correlates among more than 3,000 extant species of snakes are not well understood. Hence, we used the optokinetic response to test the visual acuity of a diverse sample with 9 species of Henophidia (boas, pythons & relatives) and 8 species of Caenophidia (advanced snakes). We tested the snakes with a large drum (diameter = 176 cm) that rotated in a horizontal plane at 3 and 9 deg/s. The smallest widths of the alternating black and white vertical stripes lining the drum ranged from 30.8-0.96 mm, which corresponded to visual acuities ranging from 0.25 - 8.0 cycles per degree (cpd). Our study is the first to determine the visual acuity of any henophidian. With only one exception, all henophidians had values of 0.5 cpd or less. Within the henophidians in our sample, similar sized terrestrial and arboreal species had similar visual acuities (0.5 cpd), whereas some small burrowing specialists such as sand boas had values of only 0.25 cpd. All of the caenophidians had visual acuities of 1 cpd or greater. A nocturnal, arboreal caenophidian with large eyes (brown tree snake) had a visual acuity of 2 cpd, whereas some similar sized semi-arboreal, diurnal rat snakes had values two to four times greater. Compared to rat snakes, the visual acuities of some extremely specialized diurnal arboreal species, such as vine and gliding snakes, were not noteworthy. In addition to retaining some primitive traits such as vestigial legs, perhaps henophidians have also retained inferior visual acuities compared to those found in advanced snakes.

121.1 DOLAN, BD*; DUGOVICH, BS; CRANE, LL; ALCANTAR, BE; JOLLES, AE; Oregon State University;
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Multiple Innate Antibacterial Immune Response Elements are Correlated in Diverse Ungulate Species

Wild ungulate species can carry and transmit various pathogens to both domestic animals and humans. It is therefore important to understand the immune response in this group of animals to better predict and manage diseases of medical and agricultural importance. We assessed the innate antibacterial immune responses of seven different ungulate species maintained in a zoological park. Numbers and types of leukocytes, the antibacterial properties of animals plasma, and the mRNA levels of Toll-like receptors (TLR) 2 and 5 were determined in aoudad (*Ammotragus lervia*), American bison (*Bison bison bison*), Roosevelt elk (*Cervus elaphus roosevelti*), fallow deer (*Dama dama*), sika deer (*Cervus nippon*), yak (*Bos grunniens*), and Damara Zebra (*Equus burchellii antiquorum*). General linear model analysis was used to examine relationships between the immune measurements. Levels of TLR2 and TLR5 mRNA in isolated leukocytes were positively correlated at the individual and species level. Additionally, TLR5 expression was related to neutrophil abundance which in turn is correlated with the ability of plasma to kill a laboratory strain of *Escherichia coli*. We also tested if innate immune responses were correlated to pace of life characteristics such as adult body weight, gestation length, or time to sexual maturity. The only relationship detected was a negative correlation between adult body weight and the ratio of neutrophils to lymphocytes. No other pattern emerged to suggest that species with fast pace of life relied more on innate immune responses than ungulates with a slower pace of life.

93.2 DOLPHIN, KE*; HOKE, KL; Colorado State University; *kedolphin@gmail.com*

Lasting Impacts of Ancestral Predation Levels on Courtship Strategy in Trinidadian guppies

Animal behavior varies based on immediate social context and cues from social partners, yet the specific patterns of behavioral plasticity may depend on abiotic environmental features or evolutionary history. Populations of *Poecilia reticulata* (Trinidadian guppies) that evolved in high and low predation environments vary in morphology, physiology, and behavioral strategies. Male guppies perform conspicuous displays known as sigmoids, which play an important role in successful courtship but also increase risk of predation. We asked how high predation and low predation populations differ in behavioral strategies to balance this tradeoff between predation risk and competition for mates. We assayed behavior of lab-reared males derived from high or low predation populations in one of five social contexts: focal male presented with two females, two females and alarm cue, one male and one female, two males, or alone. Acute stressors altered courtship behavior in opposite directions depending on ancestral population: when exposed to alarm cue, males from the low predator site increased sigmoids, while males from the high predator site decreased their sigmoid behaviors relative to trials without alarm cues. Males from the high predator population also decreased their sigmoid behaviors in response to a competitor. We are linking variation in courtship strategies to context-dependent distribution of neural activity marker pS6 throughout the brain. In total, we demonstrated different strategies of balancing the tradeoff between mating and predation in courtship depending on ancestral predation levels. Environmental shifts of these tradeoffs may have affected the evolution of the neural mechanisms underlying the sensitivity of behaviors to context.

130.2 DONATELLI, CM*; SUMMERS, AP; TYTELL, ED; Tufts University, Friday Harbor Labs, University of Washington; *cassandra.donatelli@tufts.edu*

Characterizing body twisting in elongate fishes: kinematics, mechanics, and control

Fish live in a complex three-dimensional world and need to actively adapt their swimming behavior to a range of environments. The majority of fish swimming kinematics studies focus on two-dimensional properties related to the bending wave that passes from the head to tail. In our study, we characterize how fish bodies twist around their longitudinal axis as the bending wave passes down the body. We measured this movement, which we call 'wobble', in six species of elongate fishes (*Anoplarchus insignis, Xiphister mucosus, Lumpenus sagitta, Pholis laeta, Apodichthys flavidus*, and *Ronquilus jordani*) from three different ecologies (intertidal, nearshore, and subtidal) using custom video analysis software developed in Matlab and available at https://github.com/CDonatelli/Wobble. Wobble and bending are synchronized, with a phase shift between the wobble wave and the bending wave. In nearshore species, the tail wobbles the most but, in the subtidal and intertidal species, the head wobbles more than or the same as the tail. To determine if these differences in wobble were a passive movement related to differences in the mechanics of the bodies of the fishes, or were actively controlled, we used a material testing system to measure torsional stiffness at several points from behind the head to the tail. Although stiffness increases from head to tail in all six species, amount of wobble does not. These data suggest that wobble is not a passive property in all fishes, but can be actively controlled in at least some species, potentially playing an important role in the fish's swimming behavior.

95.5 DONOHUE, MW*; KINGSTON, ACN; LIN, C; CRONIN, TW; University of Maryland, Baltimore County, University of South Carolina; *willard3@umbc.edu*

The Location of Putative Brain Photoreceptors in the Stomatopod Crustacean, Neogonodactylus oerstedii

Animals have light detectors in tissues outside of eyes, called extraocular photoreceptors, for non-visual functions like circadian photoentrainment and photolocomotory responses. Light sensitivity is most commonly achieved by visual pigments formed from an opsin protein bound to a chromophore molecule. The eyes of the stomatopod crustacean, *Neogonodactylus oerstedii*, contain dozens of opsins which probably arose through gene duplication, but we previously reported that only four opsins are expressed in the cerebral ganglion, or brain, of *N. oerstedii*. We also reported that both sighted and blinded stomatopods respond to illumination by flipping, walking, and/or swimming and suggested that stomatopods probably have opsin-based extraocular photoreceptors. Light detection is an important sensory modality for stomatopods, so the presence, location, and physiology of extraocular light detectors in these arthropods may help us predict the function of these receptors. In other arthropods, the extraocular opsin location is related to its presumed non-visual function. In the red swamp crayfish, *Procambarus clarkii*, two opsins are expressed in nerve fibers extending from the brain to the site of well-characterized caudal photoreceptors that elicit leg movements. Here, we present our data localizing opsin expression within the brain of *N. oerstedii* by *in situ* hybridization, which informs future work exploring the possible electrophysiological photoresponses of these putative receptors.

S4.11 DONOHUE, Kathleen*; EDWARDS, Brianne; BURGHARDT, Liana; Duke University; *k.donohue@duke.edu*

Interpreting variation in dormancy and germination time under diverse seasonal conditions

The timing of seed germination strongly influences fitness and the expression of life cycles in annual plants. Understanding causes of variation in germination phenology under diverse environmental scenarios would help with efforts to predict plant performance across species ranges and under conditions of environmental change. Seed germination is regulated by innate dormancy induced at the time of seed maturation and by physiological responses to multiple seasonal environmental cues that vary over time, such as water availability, chilling, and temperature. We estimated physiological parameters associated with germination responses to environmental cues in different genotypes of Arabidopsis thaliana, and measured their dormancy cycling and germination time under field conditions. We employed a developmental threshold model of germination, flowering, and overall life-cycle expression to further predict the effects of variation in specific physiological parameters of germination on the expression of whole life cycles under different simulated seasonal environmental scenarios. Genotypes with different innate dormancy differed in germination time and dormancy cycling soon after dispersal, but continued dormancy cycling reduced differences among genotypes and reduced effects of starting conditions. Initial dormancy differences are predicted to influence life-cycle expression, but auto-synchronization mechanisms that act over time under variable conditions may contribute to canalized germination.

131.1 DORMIO, SM*; MCCOY, MW; East Carolina University; *dormios15@students.ecu.edu*
Staying Active for Life: Investigating the Covariance Between Behavioral and Physiological Trade-offs in Treefrogs
While variability exists among individuals in a population, trade-offs limit the range of phenotypes an individual can express. For example, physiological trade-offs are commonly associated with the allocation of resources to growth versus development, while behavioral trade-offs can be associated with balancing between resource acquisition and predation risk. Trade-offs can also occur in the phenotypes expressed within an individual across different life stages. Behavioral consistencies, also known as personalities, may play a key role in either facilitating or setting bounds on the growth and development rates of individuals across crucial life stages. We are investigating how 1) trade-offs between individuals with "active" or "less active" behavioral personalities interact with trade-offs between growth and development, 2) how these interactions affect individual performance in habitats that favor differing strategies and 3) how these interactions drive variation among individuals in a population. Specifically, in this study we partition recently hatched *Hyla squirella* tadpoles for either activity rates (active or less active) or initial size (large or small) and compare their performance with tadpoles consisting of a mixture of these phenotypic groupings in the presence or absence of water bug predators (*Belostoma flumineum*). We find that initial phenotypes significantly affected, survival and mass, age, and snout-vent length at metamorphosis. Our results provide important insights into mechanisms that may underlie among individual differences within populations.

S9.4 DORNHAUS, Anna; University of Arizona; *dornhaus@email.arizona.edu*
Social insect colonies as individuals and groups: development and evolution of individual differences
Complex systems, where group-level function is a result of the actions and interactions of components, are ubiquitous in biology and many other fields. Such systems exhibit variation both internally (between components) and at the group level. Internal variation is often thought to be the adaptive result of individual specialization, but units may also vary in quality, robustness, and other traits; variation at the group level is often thought to be a result of noise or constraint. In social insect colonies, we now know that individual variation can be adaptive for a set of reasons in addition to generating effective division of labor; groups may therefore benefit from not employing all-specialist workers, but instead maintaining a mixture of specialized and flexible, robust and fragile, and/or cheap and expensive workers. In addition however, developmental constraints may determine how much the traits of individual workers are accessible to group-level adaptation. Variation at the group level, instead of being largely noise, may reflect individual colony life history strategy and local adaptation. Evolved variation at the group level constitutes an independent evolutionary origin (compared to variation at the level of individuals), and finding it driven by local competition, via life history strategy, reinforces the hypothesis that competition is a major driving force in the evolution of animal personalities.

36.5 DOUGHERTY, L/F*; SERB, J/M; LI, J; University of Colorado, Iowa State University; *lindseydougherty@gmail.com*
The evolution of flashing as a signal in Ctenoides ales, 'disco' clams
The ‘disco' clam *Ctenoides ales* (Limidae) is the only bivalve known to have a behaviorally mediated photic display. The flashing occurs on the mantle lip and is the result of light scattering by silica nanospheres. Ongoing studies suggest the flashing acts as an aposematic predator deterrent. The goal of this study was to investigate the evolution of the flashing display and to determine the genetic mechanism underlying the flashing. We generated a Bayesian Inference phylogeny using one nuclear (28S rRNA) and two mitochondrial (16S rRNA and COI) genes. Results reveal *C. ales* as the basal lineage in the *Ctenoides* genus, suggesting that evolution of flashing arose early when examining four *Ctenoides* species. Tissue-specific (mantle) RNAs were extracted from three *Ctenoides* species (*C. ales*, *C. scaber*, and *C. mitis*), and transcriptome libraries were sequenced. Future work will take a comparative transcriptomic approach to identify candidate genes for the flashing. In addition to the flashing display of *C. ales*, limids possess a wide array of defense mechanisms, including tentacle autotomy (*Limaria*), aposematism (*Ctenoides*), and escape swimming (*Lima*). Future work will expand the phylogeny in order to parse together morphology, habitat, and distribution to develop a complete understanding of the evolution of defenses within the Limidae.

P2.240 DOUGLAS, T*; ABRANTES, AA; MEDLER, S; SUNY Fredonia; *scott.medler@fredonia.edu*
Arterial blood supply to skeletal muscles in ghost crabs
Ghost crabs are highly active invertebrates capable of remarkable bursts of speed, as well as prolonged bouts of sustained locomotion. This study was initiated to develop better insight into how the circulatory system of the ghost crab, *Ocypode quadrata*, supplies blood to active skeletal muscles used to power locomotion. During fast sprints, the large leg muscles extend and flex the carpopodite at up to more than ten times per second. Mammalian skeletal muscles exhibit significant differences in capillary supply, based on the metabolic demands of a particular muscle, with aerobic fibers exhibiting greater capillary densities than glycolytic fibers. We perfused blood vessels with a polymerizing resin to visualize the arterial supply to the skeletal muscles of the merus. We also stained excised arteries with a variety of dyes and antibodies to elucidate their cellular and molecular organization. The results of these complementary techniques were that the entire leg is supplied by a single artery that runs along the length of the limb - midway between the dorsal and ventral borders. This artery gives rise to several smaller arteries that arise at regular intervals and then branch extensively to supply the muscle fibers of the leg. The terminal branches of this system are similar in dimension to vertebrate capillaries, and these vessels are comprised of a simple layer of squamous cells. The overall results show that the skeletal muscles are nourished by an extensive blood supply. The existence of an essentially closed arterial system in these crabs is consistent with patterns observed in other decapod crustaceans. We propose that the extensive, well-defined arterial blood supply in the ghost crabs is integral to supporting their running abilities.

94.7 DOUSSOT, C*; BERTRAND, OJN; EGELHAAF, M; University of Bielefeld, Germany, Cluster of Excellence Cognitive Interaction Technology, and University of Bielefeld, Germany; *charlotte.doussot@uni-bielefeld.de*

ACTIVE VISION STRATEGIES OF BUMBLEBEES DURING LEARNING FLIGHTS

Finding back the nest is one of the most important tasks of a bumblebee to ensure the survival of the hive. When leaving the nest for the first time, foragers perform learning flights to gather visual information about the surroundings of the nest entrance. Bumblebees are using a saccadic flight and gaze strategy to restrain the rotational components of their motion to a brief time interval called saccade. During intersaccadic intervals head rotations were previously concluded to be either negligible, which facilitates the extraction of distance cues relative to the bee (Boeddeker et al. 2015) or to be small, but actively controlled by the bee to allow for gaining distance information relative to the nest (Riabinina et al. 2014). Our current analysis has been designed to reconcile these conflicting interpretations. In the experiments a bee hive was connected to a flight arena via a vertical entrance, and departure flights of bumblebees were recorded with two high resolution cameras. This arrangement and the placement of two markers on the head facilitate the reconstruction of its orientation during the learning flights. This allows us to determine potential points in space that may be fixated during the intersaccades. Analyzing the location of these points in the arena and their retinal displacement during intersaccadic intervals provides information about their potential significance for spatial vision and thus about the gaze strategy used by the bee during their learning flights.

7.1 DOWNS, CJ*; MACCOLL, E; VANESKY, K; BUCK, JA; DUDEK, BM; EAGLES-SMITH, CA; HEATH, JA; HERRING, G; VENNUM, C; Hamilton College, Clinton, NY, Golden Gate Raptor Observatory, San Francisco, CA, US Fish and Wildlife Service, Portland, OR, Boise State University, Boise, ID, USGS, Corvallis, OR, University of Nevada, Reno, NV; *cdowns@hamilton.edu*

Correlates of Immune Defenses in Golden Eagles

An individual's investment in constitutive immune defenses depends on both endogenous and exogenous factors. We examined how population, *Leucocytozoon* parasite presence, mass scaled for structural size, heterophil:lymphocyte (H:L) ratio, and age affected immune defenses in golden eagle (*Aquila chrysaetos*) nestlings from California, Oregon, and Idaho. We quantified hemolytic-complement activity and bacterial killing ability, two constitutive measures of complement activity. Scaled mass and age did not affect immune defenses. Eagles with lower H:L ratios had lower complement activity, collaborating other studies that found that animals in better condition sometimes invest less in constitutive immunity. Results for *Leucocytozoon* presence indicate that eagles with infections had higher concentrations of circulating complement proteins but not elevated antibodies for all microbes. In addition, eagles from OR had significantly higher constitutive immunity than those from CA or ID. We posit that OR eagles might have elevated immune defenses because they are exposed to more parasites than eagles from CA or ID. Although we have incomplete data on parasite exposure for our populations, our suggestion is supported by the observation that bacteria-killing ability was higher when *Leucocytozoon* were present. By focusing on a free-living, long-lived raptor species, rather than more commonly studied passerines, our study helps develop a broad perspective regarding the evolutionary and environmental pressures on immune function in birds.

P3.244 DOYLE, JB*; ARIAS, AA; ALDANA, M; BRYAN, P; CASTRO, A; GONZALEZ, E; MEJIA, V; NORIEGA, M; VEGA, K; MEMBRENO, NA; ELSEY, RM; OWERKOWICZ, T; California State University San Bernardino, Louisiana Department of Wildlife and Fisheries; *doylj302@coyote.csusb.edu*

Cracks in Eggshells Impair Embryonic Growth in the American Alligator

Late-term embryos of archosaurs mobilise calcium from their mineralised eggshells in order to support musculoskeletal development. Previous studies on the American alligator showed that full removal of the eggshell leads to undersized embryos and hatchlings with weakly mineralised skeletons. How much of that effect is due to loss of eggshell structural integrity has not been investigated to date. We compared embryonic development and growth in eight clutches (192 eggs), collected over three seasons. Eggshells were either peeled, cracked, or sham-handled (control) at embryonic stages 16-18. All eggs were incubated for 35-40 days at 30°C in full humidity. Controlling for initial egg mass, we found that cracking the eggshell reduced embryo mass by 11%, and peeling the eggshell by 30%. Controlling for embryonic mass, whole-body proportions (total, snout-vent, femur and head lengths) were similar between treatment groups. Relative to femur length, however, wet mass of the caudofemoralis muscle (a major hind limb retractor) was significantly reduced in embryos from cracked (-9%) and peeled (-23%) eggs. Eggshell fracture was unlikely to compromise calcium supply, given that eggshell crystals retained an intimate association with the underlying shell membrane. Overall, we show that eggshell fracture during rough handling/transport of eggs can have deleterious effects on embryonic growth and may impair hatchling escape performance from the nest. Our findings have implications for crocodilian conservation and egg ranching efforts, and may impact egg collection methods to minimise eggshell fracture. Further, researchers working on crocodilian eggs should consider controlling for structural integrity of eggshells in their studies.

133.2 DREIER, M.*; COTA, C.; DAVIDSON, B.; Swarthmore College, Swarthmore, PA; *mdreier1@swarthmore.edu*

Mitotic coordination of membrane trafficking in Ciona intestinalis heart development

During cell division, cell components must be segregated in an organized manner. Mitotic segregation of components can control cell identity and behavior. In the case of growth factor receptors, proper segregation during division is of particular importance because excess growth factor signaling can lead to cancer. However, little is known about membrane trafficking during mitosis or the mechanisms that control it. Here, we demonstrate that mitotic membrane trafficking is correlated to and dependent on the activity of mitotic kinases in embryonic *Ciona intestinalis* heart founder cells. Based on automated tracking of foci from *in vivo* live images, we report that subcellular movements of the integral membrane protein Caveolin are correlated with the progression of mitosis. Inhibition of the mitotic kinases CDK1 and PLK1 demonstrate that each is required for facets of mitotic FGF Receptor trafficking, including internalization and localization to the cytokinetic furrow, respectively. These results suggest that mitotic kinases coordinate membrane trafficking during mitosis. Uncovering the mechanisms underlying mitotic control of trafficking pathways may define new pathways that regulate cell signaling and shed light on mechanisms controlling cell fate induction. A description of growth factor receptor segregation during mitosis will suggest ways in which improper segregation can lead to abnormal cell fate, behavior, or malignancy.

P2.138 DRISCOLL, RMH*; HURD, PL; RENN, SCP; Reed College, University of Alberta; *rosdrisc@reed.edu*

Evidence for aromatase gene and enhancer methylation in P. pulcher, a cichlid species with environmental sex determination

In most systems, the sex determination mechanism of a species has evolved to maintain a 50:50 sex ratio, but an even mix of males and females in every brood is not required. In species with environmental sex determination, it may be advantageous for parents to produce more males at one time of year and more females at another, as environmental conditions change. In the African cichlid fish *Pelvicachromis pulcher*, sex determination is influenced by water pH during the first 30 days of life, producing a male bias at lower (acidic) pH and a female bias at neutral pH. pH also has an affect on phenotype within a sex: There are (at least) two common male morphs that differ in color and reproductive behavior, and the expression of these alternate phenotypes is also influenced by pH. Methylation of the gonadal aromatase gene (cyp19a1A), which converts testosterone to estrogen, has been linked with temperature sex determination in other teleost species, but has not been investigated as a mechanism for pH dependent sex determination. We will report on gonadal as well as brain (cyp19a1B) aromatase methylation status in *P. pulcher*. We demonstrate an experimental paradigm for a detailed temporal study to identify the critical period for environmentally sensitive aromatase methylation, focusing on *P. pulcher* fry development over the first 60 days of life. We compare fish raised in acidic and neutral conditions.

P1.170 DROLET, J*; VEZINA, F; Universite du Quebec a Rimouski; *justine.drolet@hotmail.com*

Testing the myth of humid versus dry cold : birds don't care.

Water vapor in the air can influence heat exchanges between an animal's body and its environment but, below the freezing point, as the air water vapor pressure is very low due to condensation, it is often assumed that the effect of humidity on small endotherm's thermoregulation is negligible. However, a recent study showed that black-capped chickadees (Poecile atricapillus) from eastern Canada had higher maximal thermogenic capacity (Msum) on winter days with higher humidity. This suggests that the cooling effect of humid air might be perceived by birds even in cold environments. To test this hypothesis, we measured resting metabolic rate (RMR) of captive chickadees (n = 10) during exposition to two ambient temperatures (-10°C and 10°C) while receiving either dry air or air saturated with water vapor. Preliminary results show that birds had an RMR 43% higher when at -10°C than at 10°C but that RMR did not vary with humidity at any temperature. Our results therefore suggest that chickadees do not loose more heat when being exposed to humid air. Feather insulation may be involved in this process by preventing significant changes in water vapor of the air layer close to the skin.

P3.248 DUBANSKY, B.H.*; HOANG, A.N.; Tarleton State University; *dubansky@tarleton.edu*

Crocodilian Skin as a Model for Studying Soft Tissue Mineralization in Human Disease

Irreversible pathologic mineralization of soft tissue occurs with numerous human diseases and can be a side effect of some medical procedures and traumatic injury. Because the mechanisms of this mineralization process are not well understood, there are no consistently effective treatment strategies besides surgical excision, which does not always prevent reoccurrence of the bony lesions. Animal models that naturally produce mineralized deposits (i.e., osteoderms) in their skin have never been utilized for studying these pathologic mechanisms in human disease. In this study, alligator osteoderms were collected at multiple time points up to one year post-hatching. Bone formation in the skin was documented using classical histological staining and antibody staining for mechanistic markers of epithelial/endothelial-to-mesenchymal transition and ossification. The development of osteoderms in crocodilians resembles that of pathologic mineralization in human skin; namely through fibrosis and subsequent metaplastic conversion of connective tissue to bone. This study shows that using an animal model that undergoes natural soft tissue mineralization allows a multi-system, holistic approach to studying the analogous human disease process, which is not possible with lab-generated models (e.g., cell culture or implant specimens). Crocodilians may also prove useful as models for other human disorders that involve soft tissue mineralization including calcification of atherosclerotic plaques, connective tissue diseases, and autoimmune diseases.

42.5 DUBANSKY, B*; BURGGREN, W; University of North Texas; *benjamin.dubansky@unt.edu*

Ventricular pressure in larval precocial and altricial teleost fishes exposed to environmental contaminants

The developing heart is a sensitive indicator of the effects of environmental stressors such as polyaromatic hydrocarbons (PAHs), a class of ubiquitous environmental contaminants. Resulting changes in morphology, edema, arrhythmias and heart rate changes and disruptions to cardiac output are common endpoints that can be measured optically, providing a general overview of cardiac performance and indices of effect. Indeed, these endpoints have become a cornerstone for assessing the effects of PAH toxicity in vertebrate species. Determination of blood pressure requires physical intervention, but reveals fine-scale physiological patterns of hemodynamic performance. Servonull pressure systems are capable of recording pressures in micron-sized chambers, such as the embryonic fish heart. Cardiac function of the red drum (*Sciaenops ocellatus*) and the Gulf killifish (*Fundulus grandis*) were assessed through larval and juvenile stages to compare altricial and precocial modes of development following exposure to PAHs. Development of blood pressure with respect to heart rate and cardiac output revealed patterns of heart function that correlated with mode of development and functional constraints imposed by developmental timing (e.g. onset of gill function, swimming, feeding, etc.) Alterations in blood pressure associated with exposure to the toxicants were more closely related to an overall delay in development than directly to the stressor. These studies demonstrate the use of fine scale physiologic measures to assess the functional role of the cardiovascular system in the teratogenicity of PAHs, and the ontogeny of cardiovascular function in two emerging aquatic model species.

28.5 DUDDLESTON, K/N; Univ. Alaska Anchorage;
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Investigating the Gut Microbial Community of an Extreme Hibernator, the Arctic Ground Squirrel

Hibernation is a physiological adaptation to reduced food availability characterized by profound fluctuations in diet and physiology. The arctic ground squirrel is the northern most hibernator and exhibits the most extreme hibernation physiology. They reproduce and grow over a 3-4 month active season, increasing fat mass from ~ 5% to over 45% during the last 3 weeks in preparation for hibernation. Hibernation lasts up to nine months, during which they neither eat nor drink, and bouts of torpor (periods of decreased body temperature (Tb), metabolic rate and activity) last up to 25 days, interspersed with periodic arousals to euthermy. During torpor Tb is regulated at -2.9C, the lowest of any mammal. We have demonstrated that seasonal changes in host physiology affect the cecal microbial community of arctic ground squirrels, and that hibernation selects for a core cecal microbiota. Microbial diversity in juvenile squirrels is strongly influenced by genetic or maternal influences and does not shift significantly during pre-hibernation fattening; however, relative abundances of major taxa reflect the obese microbiota observed in other species. We have also found that gut microbial community structure in adult arctic ground squirrels is robust to changes in dietary fat content across the active season, but is responsive at the level of gene expression, perhaps suggesting strong host selection for a fattening microbiota regardless of diet. Finally, in an effort to uncover important functional relationships between arctic ground squirrels and their gut microbiota, we are isolating and characterizing beneficial ureolytic bacteria from the gut, and examining host reliance upon urea nitrogen salvage to conserve protein during the hibernation and active seasons.

P2.86 DUDLEY, EM*; DAVIS, JE; BIANCHI, L; CLELLAND, IJ; RAY, A; Radford University; *emdudley@radford.edu*

An examination of food consumption and the production of nutrient rich frass by Gromphadorhina portentosa colonies treated with royal jelly.

Insects play an essential role in maintaining the health of an ecosystem through the decomposition of organic material into nutrients and energy cycled through the food web. Due to their large size, tolerance for high population density, and opportunistic feeding, *Gromphadorhina portentosa* can metabolize large quantities of a wide variety of potential foodstuffs. Our previous research has shown that royal jelly, produced by honeybees, increases the growth rate and fecundity of *Gromphadorhina portentosa* when administered throughout their life cycle. In this presentation, we examine royal jelly and how it may affect the rate of conversion of organic material eaten by *Gromphadorhina portentosa* into nutrient rich frass. Preliminary data suggests a positive trend between consistent royal jelly treatments and food consumption in controlled laboratory colonies. In order to explore the effects of long-term and short-term royal jelly treatments on *Gromphadorhina portentosa*, we administered royal jelly to colonies of cockroaches treated with royal jelly from the beginning of their life and colonies of previously untreated cockroaches while observing various aspects of food consumption including mass and diversity of foods consumed, and measurement of fecal production. These colonies were compared to control colonies of untreated cockroaches fed a similar diet. We will discuss possible contributions of this research to reduction of human impact on ecological processes.

P1.100 DUDLEY, C*; FOOTE, S; DAVIS, T; HORN, R; MILLER, B; SCHREIBER, AM; St Lawrence University, NY;
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Matrixmetalloprotease Activity is Required for both Longitudinal and Cross-sectional Intestinal Remodeling during Xenopus laevis Metamorphosis

Metamorphosis of the herbivorous tadpole into a carnivorous frog is accompanied by an abrupt remodeling of the gut: the intestine shortens by 75%, the connective tissue and smooth muscle layers thicken, enteric neuronal cell bodies form clusters, and the lumen becomes highly involuted. Virtually all aspects of amphibian metamorphosis are mediated by thyroid hormone (TH), and the mRNAs of several matrixmetalloprotease (MMPs) are known to be upregulated directly (stromelysin-3) or indirectly (gelatinase A and MT1-MMP) in the gut mesenchyme by TH. However, the specific roles of MMP enzymatic activity on intestinal remodeling have not been well-described. Here we show that treatment of pre- and pro-metamorphic tadpoles with a broad-spectrum inhibitor of MMP activity (doxycycline, DOXY) inhibits 25-35% of intestinal MMP activity. Furthermore, in the presence of DOXY, TH treatment failed to induce virtually all aspects of metamorphic intestinal remodeling, including gut shortening, thickening of the mesenchyme and smooth muscle layers, and the development of involutions on the lumen. These findings directly support the hypothesis that an upregulation of TH-responsive MMP activity during metamorphosis mediates diverse changes that accompany intestinal remodeling.

87.1 DUELL, ME*; HARRISON , JF; Arizona State University;
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Some don't like it hot: Variation in stingless bee flight performance as a function of air temperature

Environmental temperatures strongly affect the fitness of ectotherms, but these effects depend on body size. The "temperature-size rule" describes the pattern that ectotherms living in hotter environments are typically smaller, suggesting that smaller ectotherms might have selective advantages in hotter temperatures. We measured flight performance and body temperature across a range of air temperatures in field and lab settings using ten species of stingless bees varying in body mass from 2-120mg. We also measured air, leaf, flower, and bee temperatures in the forest canopy, where stingless bees forage, using a canopy crane. Smaller species flew with body temperatures much closer to air temperature than larger species, which fly at temperatures up to 10°C in excess of air temperature. This pattern is explained by the scaling of heat gain and loss; thermal conductance scaled with mass$^{0.5}$ while flight metabolic rate scaled with mass$^{1.1}$. The shape of thermal performance curves from 25-42°C varied strongly by species, with flight metabolic rates increasing strongly in some species, decreasing strongly in others, and being independent of temperature in others. This result suggests species may respond differently to seasonal and climatic thermal variation. The critical thermal maximum temperature at which flight ceased was lower in smaller species, possibly because larger endothermic species routinely experience higher body temperatures. Finally, we compare body sizes of these species over four years, which have increased greatly in average daily air temperature. Body size did not decrease in most species as suggested by the temperature-size rule. Instead, we find greater variation in body size, both smaller and larger among forager stingless bees as average air temperature increased annually.

138.1 DUMONT, ER*; HEDRICK, B; DáVALOS, LM; ROSSITER, S; SEARS, KE; DUMONT, Elizab; UMass Amherst, Stony Brook University, Queen Mary University of London, University of Illinois, Urbana; *bdumont@bio.umass.edu*

The morphology of the bat sensory system: correlates of sight, chemosensation, and hearing in noctilionoid bats

Through their long evolutionary history bats have diverged in their relative reliance on different senses; some species rely heavily on sight, others on hearing, and others on nasal and/or vomeronasal chemoreception. However, no species demonstrates extreme specializations in all three systems, suggesting that there may be trade-offs among them. The signatures of differential specialization on sensory systems should be evident in bat genomes, developmental processes, adult phenotypes. The ultimate goal of our work is to identify links between genomic, molecular developmental, and morphological aspects of variation in sensory systems in order to identify intrinsic drivers of ecological and taxonomic diversification. Our project focuses on noctilionoid bats because they encompass a wide variety of sensory specializations and there is a wealth of genetic, developmental, and morphological studies on which to build. Here we characterize skull shape in noctilionoid bats using micro-ct scanning and 3D geometric morphometrics (GM) to evaluate the relationship between skull shape and the size and distribution of soft tissues associated with vision, hearing, and chemoreception. We investigate associations between 3D GM data and soft tissue morphometry in order to explore whether and how skull shape reflects the structure, size, and distribution of soft tissues associated with vision, hearing, and chemoreception. Our quantitative assessments of the size, shape, and distribution of bony and soft tissue structures provide a platform for evaluating relationships among genotype, developmental mechanisms, and phenotype, and for testing the hypothesis that there has been competition among sensory systems.

P3.134 DUNN, P.O.*; JOHNSON, J.A.; MORROW, M.; WHITTINGHAM, L.A.; Univ. of Wisconsin-Milwaukee, Univ. of North Texas, US Fish & Wildlife Service; *pdunn@uwm.edu*

What Genes are Important to Survival in One of America's Most Endangered Birds?

The negative effects of inbreeding on fitness are serious concerns for populations of endangered species. For example, inbreeding is associated with lower survival in captive populations of Attwater's prairie-chicken (Tympanuchus cupido attwateri), which is one of the most endangered birds in America. However, it is not known if inbreeding affects survival of birds released into the wild from the captive breeding program. Here, we examined 20990 SNPs from ddRAD sequencing to determine what genomic regions are associated with survival after release into the wild. We found that post-release survival of captive-bred birds was related to alleles of the innate (toll-like receptors, TLRs) and adaptive (major histocompatibility complex, MHC) immune systems, but not to genome-wide heterozygosity. Overall, this study provides a critical step in genetic rescue efforts by discovering regions of the genome that are related to fitness.

P1.44 DUQUE-MENDOZA, FG*; RODRIGUEZ-SALTOS, CA; Georgia State University, Emory University; *fduque1@student.gsu.edu*

Exceptionally high fundamental frequencies in a bird vocalization

Hearing is often tuned to acoustic features in conspecific vocalizations. For example, in birds, most vocalizations are in a frequency range between 1- 6 kHz, with some reaching 9 kHz. The frequency sensitivity of most birds also falls within this range, considerably lower than that of many species of mammals. Here, however, we describe vocalizations from an Andean hummingbird that are well above the maximum frequency reported for other birds. The Ecuadorian Hillstar (*Oreotrochilus chimborazo*) is a hummingbird living in high-altitude ecosystems in the northern Andes. We recorded four individuals from different populations, finding in all of them high frequency vocalizations. The fundamental frequencies ranged across individuals from 10.72 ± 0.45 kHz (mean ± SEM) to 16.60 ± 0.64 kHz, and harmonics exceeded 28 kHz. The complexity of the vocalizations was reminiscent of song in other species of birds; they were tonal, rich in frequency modulations, and had a duration of 1.13 ± 0.13 sec, which is longer than that of regular calls in hillstars. We also observed that these vocalizations are stereotyped within individuals, although variations between individuals occur. Among the hillstars, only males seem to produce these vocalizations, typically while sitting atop perches as if overseeing their territories. Though other studies have reported high frequency vocalizations in birds, these were either transient or harmonics of much lower fundamental frequencies. Given the complexity of these vocalizations and the context in which they are produced, it is likely that they function as songs.

41.6 DURSTON, NE*; WAN, X; LIU, JG; WINDSOR, SP; University of Bristol, UK, Imperial College London, UK; *Nick.Durston@bristol.ac.uk*

High resolution three-dimensional surface measurements of birds of prey in gliding flight

Accurately measuring the wing shape of flying animals is of great importance for accurate aerodynamic analysis. This is because the flow phenomena and resulting forces and moments are sensitive to subtle changes in shape. Historically, aerodynamic analysis of birds has mostly been reliant on approximate models of wing geometry or the use of animal cadavers placed in approximate flight configurations. Both of these approaches suffer the limitation that they are unlikely to accurately reproduce the in-flight geometry. Here, a new method for high resolution three-dimensional geometric measurement of free-flying birds is presented. A trained barn owl (*Tyto alba*) and peregrine falcon (*Falco peregrinus*) were flown outdoors past a set of eight synchronised DSLR cameras arranged in pairs above and below the bird's flight path. The complete surface geometry of the bird in steady glide (approx. 1 million points) was measured using the new photogrammetric technique which is based on a phase correlation approach. The demonstrated accuracy of this new method is ± 2.5 mm for 95% of the points based on measurement of a life size model bird made under field conditions. The accuracy and resolution of the measurements far exceed anything so far achieved in bird flight research, and stands to significantly improve the accuracy of future analysis of bird aerodynamics and flight dynamics.

P1.82 DYKEMA, Z*; BERTUCCI, E; NERI, C; MACKENTLY, N; LINDSAY, A; Northern Michigan University, Whitefish Point Bird Observatory, Whitefish Point Bird Observatory; *zdykema@nmu.edu*

Different Audiolures Lead to Different Sex-Ratio Biases in Northern Saw-whet Owl (Aegolius acadicus) Captures at Whitefish Point Bird Observatory

Northern Saw-whet Owls (*Aegolius acadicus*) are banded across the United States, yet neither migration nor dispersal of Northern Saw-whet Owls are completely understood. In 2007 and 2008, the banding station at Whitefish Point Bird Observatory in Michigan's Upper Peninsula began using male and female (respectively) audiolures at some owl capture sites to complement the passive mist netting that had been underway since 1994. We analyzed data from spring owl captures (1994-2015) that used either male "advertising call" audiolures, female "tssst" audiolures, or no audiolures. From the analysis of 6600 birds captured in that period, we demonstrate that 1) there was a substantial female bias in the owls caught in the passive and male audiolure nets, 2) a more extreme female bias was caught in the male audiolure nets, and 3) a nearly equal proportion of male and female owls were caught in the female-audiolure nets. The results of this analysis can be used by other researchers to provide higher capture rates of male Northern Saw-whet Owls at their stations, and should be considered when making inferences about Northern Saw-whet Owl demographics based on banding records.

91.1 DZIALOWSKI, EM*; SIRSAT, TS; Univ. of North Texas; *edzial@unt.edu*

Influence of Thyroid Hormones on Development of Endothermy in the Precocial Pekin Duck

At hatching, precocial Pekin ducks rapidly undergo physiological and metabolic changes associated with expression of an endothermic phenotype. Thyroid hormones (TH) are key regulators of avian metabolism and are thought to regulate the development of endothermy. To better understand the role of TH in the Pekin duck's endothermic developmental trajectory, we characterized systemic O2 consumption (Vo_2) and ventilation (frequency and tidal volume) in the thermal neutral zone and during cooling under hypothyroid conditions via administration of the thyroperoxidase inhibitor methimazole (MMI, 87.57 mM/kg) and hyperthyroid conditions via triiodothyronine (T3, 297 µM/kg) supplementation. Animals were dosed on day 24 of a 28-day incubation period and studied on incubation day 25, during external pipping (EP), and 1-day post hatching (DPH). On day 25, there was an increase in Vo_2 in the hyperthyroid group compared with the other two groups. During the EP stage, there was a significant effect of thyroid status on Vo_2 with hyperthyroid being highest and hypothyroid lowest. By 1DPH, the hyperthyroid and control animals had the same Vo_2 response to cooling: a thermal neutral zone followed by an increase in Vo_2. The hypothyroid 1DPH animals had a lower resting Vo_2 that did not increase to the same extent as the hyperthyroid and control animals during cooling. During EP, hypothyroid animals had lower ventilation frequency and tidal volume than control and hyperthyroid animals. As 1DPH, ventilation frequency of all animals increased during cooling while tidal volume only increased in hyperthyroid and control animals. Our data suggest TH plays an active role in systemic development of endothermic metabolic capacity. In the neonate avian, multiple systems develop in concert to produce an endothermic phenotype, but reduced TH can delay maturation of endothermic capacity in this species.

P1.79 EARL, SC*; NOVARRO, AJ; SUNY ESF, University of Maryland; *scearl@syr.edu*

Competition strategies of the eastern red-backed salamander

Good competitors will be able to effectively reduce both interspecific and intraspecific competition by developing life strategies to limit competitive interactions. These life strategies partition resources through generalistic behaviors, territorial behavior, and ontogenetic shifts in diet or habitat. It is essential that Plethodontid salamanders exhibit these life strategies in order to be well-suited competitors because they are vulnerable to environmental stressors due to their unique physiology. *Plethodon cinereus* seem to be good competitors due to their relatively high abundance and wide geographic distribution. We studied the life strategies that help *P. cinereus* reduce interspecific and intraspecific competition by means of diet selectivity and diet change between age classes. We hypothesized that *P. cinereus* would be generalists and exhibit an ontogenetic shift in diet which would classify the species as good competitors. We analyzed the invertebrate community of three varying vegetation types and compared the available prey to the gut contents of adult salamanders. Red-backed salamanders can be classified as generalists because the abundance of invertebrates in the gut contents correlated with the abundance of invertebrates available at each vegetation type. *Plethodon cinereus* does not experience ontogenetic shift when analyzing shifts in weight and percent weight of invertebrate orders between age classes. The red-backed salamander may not need to reduce intraspecific competition through ontogenetic diet shift because of its territorial behavior. This approach to analyze competitor suitability can be used to relatively compare species by assessing their ability to reduce interspecific and intraspecific competition. Further refining this method can be applied to conservation efforts as well as species risk assessments.

P1.179 EARLY, C. M.*; WITMER, L. M.; Ohio University; *ce643812@ohio.edu*

Inferring Vision-related Neuroanatomy and Behavior from the Brain Endocasts of Birds

Avian brain endocasts are relatively faithful representations of the external morphology of the brain, and in extinct birds, they are the only source of information on brain anatomy. The volumes of some brain structures in extant birds have been correlated with the complexity of the behaviors that they mediate. Often, these correlations are used to make inferences about behavior in extinct birds, but these inferences are based on endocast structures and rely on the assumption that the surface area of an endocast structure is a fair proxy for the volume of the underlying brain structure. However, this assumption has not been tested and may be problematic because the endocast only allows measurement of the surface area of externally-visible portions of brain structures. The optic lobe, which overlies the optic tectum, and the Wulst, which overlies the hyperpallium, are two endocast structures which are consistently expressed in birds and whose associated brain structures are involved in avian visual pathways. The relationships of these brain and endocast structures were assessed in 20 extant avian taxa. For each species, optic tectum and hyperpallium volumes, compiled from the literature, were regressed on the surface areas of the optic lobe and Wulst, measured from endocasts generated from CT scan data. These preliminary results indicate that there is a positive relationship between endocast structure surface area and brain structure volume in the studied vision-related structures, which was then used to predict the volumes of these brain structures in five extinct avian taxa (*Archaeopteryx*, *Dinornis*, *Lithornis*, *Presbyornis*, and "*Buteo*" *grangeri*). This taxonomic sample will be expanded in the future to strengthen these relationships and extend the study of brains and behavior of birds into deep time.

P2.225 EBERL, R*; BAIR, J; CHOW, B; ROSA-BARNETTE, S; STURBAUM, Z; COHEN, CS; San Francisco State University, Santa Rosa Junior College; *reberl@sfsu.edu*

Sea Star Wasting Disease and Leptasterias spp. abundance in Central versus Northern California

Sea star wasting disease (SSWD) is impacting ecological communities along the Pacific coast. Multiple environmental stressors such as changes in temperature, salinity, or pH might increase susceptibility to SSWD. Surveys of changes in sea star abundance are an important tool for understanding the spread and impact of the disease on marine communities. Many survey efforts focus on the larger stars including the keystone predator *Pisaster ochraceous* that suffered initial drastic population declines from SSWD but has recently shown some localized signs of recovery. In contrast to *P. ochraceous* and other stars that disperse via larvae and can re-colonize large areas decimated by SSWD, the small cryptic six-armed sea star *Leptasterias* spp. brood its young. Brooding stars tend to have minimal gene flow between populations, which leads to the potential of both reproductive isolation among relatively close sites and greater fluctuation in population density over time. An analysis of abundance surveys conducted in central and northern California during the period 2010 to 2016 shows differential but sometimes-drastic declines in *Leptasterias* abundance. The onset of decline in *Leptasterias* abundance appears to be later than in larger-bodied sea stars. In central California multiple local populations appear to have been extirpated. Populations in northern California presently show levels of abundance similar to what was previously found in central California despite the fact that symptomatic stars are found in these locations. Given the life history of *Leptasterias* spp. recovery from SSWD in severely impacted populations in central California may be unattainable over a short time frame.

P2.274 ECAY, TW; STEWART, J R*; East Tennessee State University, Johnson City; *tomecay@gmail.com*

Calcium Transport by the Chorioallantois of Trachemys scripta Is Independent of Calbindin-D_{28K} Expression

The eggshell is a calcium storage depot accessed by oviparous reptile embryos. Eggshell calcium is mobilized into embryonic tissues of turtles and squamates late in development. In contrast, bird embryos mobilize calcium earlier in development and deposit it in both yolk and embryonic tissues. The chorioallantoic membrane, which lies adjacent to the eggshell, is responsible for solubilizing and transporting calcium. We have shown that squamate chorioallantois expresses the epithelial calcium transport marker protein calbindin-D_{28K} late in development coincident with calcium transport. Studies by others show that chick chorioallantois does not express calbindin-D_{28K} at any stage of development. These results suggest that squamate chorioallantois calcium transport is similar to mechanisms of intestinal or renal epithelia but that birds express a different (perhaps unique) chorioallantois calcium transport mechanism. We used immunoblotting for calbindin-D_{28K} in the turtle (*Trachemys script*) chorioallantois to test the hypothesis that similarity in the pattern of calcium mobilization between turtles and squamates reflects functional similarity in the mechanism of calcium mobilization. In a developmental series of tissue samples from six egg clutches, we find little evidence for calbindin-D_{28K} expression in the chorioallantois. However, yolk splanchnopleure expression of calbindin-D_{28K} follows a similar developmental pattern observed in both squamates and birds. We conclude that the mechanism of calcium mobilization from yolk is conserved across reptilian lineages, but that specializations for calcium transport by the chorioallantoic membrane are independent of the ontogenetic pattern of calcium mobilization and may reflect phylogenetic patterns.

142.3 EDDY, D*; STAGER, M; CHEVIRON, ZA; CARLING, MD; University of Wyoming, University of Montana; *douglitas@gmail.com*

Assessing the Metabolic Costs of Avian Malaria in a Temperate Songbird (Junco hyemalis)

Small endotherms face high energetic costs to maintain physiological function in seasonal environments. Often, important life history stages involve competing energetic demands (e.g., breeding, migration). If, for example, an individual's aerobic performance is negatively impacted by mounting an immune response, infected individuals may experience an energetic trade-off that could lead to reductions in either aerobic performance or immune defenses. If the costs of both traits are additive, an organism may be required to increase energy intake, decrease activity, or both. Alternatively, if the costs of aerobic performance and immune function are antagonistic, increased allocation to either function may result in reductions to the other. To understand the costs of infection, we tested these resource allocation hypotheses in a songbird, the Dark-eyed Junco (*Junco hyemalis*), by measuring aerobic performance and avian malaria infection status. We measured the intensity of malaria infection in breeding adult birds, as well as resting metabolic rate (RMR), summit metabolic rate (M¬sum), and metabolic scope (the difference of [Msum-RMR]). Preliminary data suggest that infected birds increase RMR and decrease Msum, resulting in a reduced aerobic scope. If malaria infection reduces Msum, scope, or both, it is likely that infected birds will be unable to respond to aerobic challenges as well as uninfected birds. These findings may provide evidence that essential physiological functions compete for resources during avian malaria infection. Our research adds to the growing body of evidence that avian malaria infection, even at low levels, can impact whole organism performance and fitness.

S7.5 EDGECOMBE, Gregory D.; The Natural History Museum; *g.edgecombe@nhm.ac.uk*

Inferring arthropod phylogeny: Fossils and their interaction with other data sources

The past five years have witnessed a renewed interest in discrete morphological characters as a source of phylogenetic data, after a decade or more of their dismissal in favour of molecules-only approaches. This has stemmed to some degree from phenomic methods (i.e., amassing character sample of sufficient sizes to take advantage of the statistical power that had hitherto been exclusive to molecules), but also from refinements in total evidence dating and morphological clock analyses, both of which require morphological character matrices and temporal data from fossils. The unique contribution of palaeontology is stem groups, revealing the sequence of character acquisition in long-branch terminals (such as the euarthropod stem group) and otherwise unknown morphologies (like armoured lobopodians and radiodontan giant predators in the onychophoran and euarthropod stems, respectively). The origin of mandibles exemplifies an integrative approach: 1) transcriptomics defends a single origin of mandibles in the clade Mandibulata; 2) Cambrian fossils inform on morphological changes in the gnathal appendages in the mandibulate stem group; 3) molecular dating, calibrated by fossils in novel modes of exceptional preservation, draws the mandibulate stem into the early Cambrian; 4) gene expression in extant taxa identifies genes that specify mandibular identity from a trunk limb-like precursor.

P3.237 EDWARDS, E.A.*; SU, A; Cleveland State Unversity, Cleveland State University ; *e.a.edwards46@vikes.csuohio.edu*

Variation of bone microarchitecture within and among contemporaneous species of fossil horses: feasibility

Mesohippus, Miohippus, and *Merychippus* are three extinct horse species that date back fifteen to thirty million years ago, which spanned over three time periods in North America. Each of the horses habituated different terrains from swampy wet lands to dry savanna lands. Throughout time, the three species have shown a shift from tridactyl to monodactyl. The one-toe that has become prominent is the third metacarpal, which is the specimen of this study. The aim was to find a correlation with the third metacarpal bone thickness and terrain where species lived, which would support Wolff's Law. Methods were conducted to discover the likelihood of being able to carry out this procedure with each horse fossil specimen that was obtainable. Imaging of the third metacarpal was accomplished by micro-CT scanning with a focus on the distal end. Each specimen was standardized using methodical steps to show feasibility. Reorientation was used to align anatomical landmarks of each fossil. Segmentation was performed and separated bone from non-bone. Volumes of interest were determined based on specimen size to reflect relative areas for comparison. The bone within these VOIs were able to be isolated into trabecular and subchondral bone for further quantitative analysis. Evolution of the equine foot is also important for equine health, particularly the orthopedic area of equestrian sports. This research also can provide information to equine foot paleontology-helping build fossil history. The data that supports equine orthopedics can analogously be converted to human orthopedics, particularly osteoporosis. As a feasibility study for future bone microarchitecture, this analysis serves to present an enhanced understanding of standardizing the third metacarpal of horse fossil bones.

60.8 EDWARDS, D/D*; MOORE, P/A; Bowling Green State University; *davide@bgsu.edu*

Don't be such a drag: A. lycorias (Perlidae) body posture changes with increasing water velocity and respect to individual body shape

Stream insects must cope with and respond to changing abiotic conditions in their immediate habitat. The major abiotic factor influencing stream organism physiology, morphology, and behavior is water movement. Physical forces (i.e. - drag and lift) associated with water movement will influence how an insect resides on benthic substratum. For this reason, body shape couples organism morphology to turbulent stream flow. Previous work conducted has identified correlative evidence of Acroneuria sp. (Perlidae) body shape morphology and flow characteristics of the habitat. We wanted to evaluate this further to identify behavior (postural) changes and associated drag experienced by the animal with respect to individual body shape morphology under increasing water velocity. Acroneuria lycorias were collected from three streams in Michigan's Northern Lower Peninsula and retained in artificial stream channels. Individuals were placed on a platform attached to a Phidgets load cell (0 - 100g) in a recirculating flume while water velocity was controlled by a rheostat propeller. Behavior and drag measurements were simultaneously recorded for each animal while alive and dead in an attempt to separate behavior and morphological effects on drag. A preliminary geometric morphometrics approach quantified variation in body shape morphology. As a result of body shape variation, A. lycorias appear to have particular behaviors to counteract the force of drag on the body. Understanding body shape morphology and associated behavior can help elucidate important flow characteristics of the stream habitat.

6.3 EERNISSE, DJ*; IBAÑEZ, CM; California State University, Fullerton, USA, Universidad Andres Bello, Santiago, Chile; *deernisse@fullerton.edu*

Clearing up taxonomic confusion in South American Tonicia (Mollusca: Polyplacophora)

The shell-eyed chitons of the genus, *Tonicia* Gray, 1847 (Chitonidae), are restricted to the tropical and southern hemisphere coastlines of the New World. Their greatest diversity is found along the South American coast of Chile, where they are also ecologically important and conspicuous grazers. Yet study of their biology is hindered by a long history of name confusion, including the widespread usage of two names, *T. elegans* (Frembly, 1827) and *T. lineolata* (Frembly, 1827). Unfortunately, these are preoccupied names that need to be replaced with the next oldest available names. The problem became even more convoluted when we undertook, with other co-authors reported elsewhere, a study of their molecular systematics, and the molecular clades did not correspond in all cases to the species concepts currently is use. This led us to investigate the type material of the oldest nominal species, almost exclusively housed at the Natural History Museum, London. Here we recount how with considerable help provided by the museum staff, we eventually came to assign names to the seven South American species we consider valid, but whose identity is shuffled compared to names in usage now. Better resolution of this genus has provided opportunities for investigating ecological, reproductive, morphological, and biogeographic aspects of an endemic South American evolutionary radiation. Funding has been provided by NSF (DEB 1355230 to DJE) and FONDECYT (1130266 and 3140610 to CMI).

P2.120 EGAN, AN*; DRYMON, JM; DALY-ENGEL, TS; University of West Florida, University of South Alabama; *arieln.egan@gmail.com*

Multiple Paternity Variation Over Time of the Atlantic Sharpnose Shark (Rhizoprionodon terraenovae)

The Atlantic sharpnose shark *(Rhizoprionodon terraenovae)* is an abundant, small coastal shark found in temperate and tropical waters of the western Atlantic and Gulf of Mexico. Life history characteristics in this species are generally established, but the occurrence of multiple mating by females (polyandry) as a reproductive strategy remains undocumented. Studies indicate that polyandry is common among sharks, but to date no small coastal sharks have been studied. For this study, muscle tissue samples from 80 *R. terraenovae* broods were collected off the coast of Alabama. DNA will be extracted from all samples and microsatellite markers applied for parentage analysis. With these data, we aim to discern the occurrence and frequency of multiple mating in *R. terraenovae* over several reproductive seasons to examine how this trait varies over time. The results and information from this study may provide additional information about genetic diversity of the *R. terraenovae* population in the Gulf of Mexico. Different reproductive strategies can influence genetic diversity and fitness, and are therefore of interest for conservation management. If multiple paternity proves to be common in *R. terraenovae*, potential population-level consequences of exploitation by fisheries may need to be assessed to understand how fisheries affect the genetic diversity of this species.

71.6 EITING, TP*; WACHOWIAK, DM; Univ. of Utah; *tom.eiting@utah.edu*

Effects of sniffing on olfactory bulb processing revealed by in vivo imaging from defined neuron types

Sniffing and analogous sampling strategies are known from most classes of animals. Among mammals sniffing allows rapid and efficient odor sampling; initial responses and simple discriminations can occur after the first sniff (~ 200 ms). However, mammals often sniff in bouts lasting up to 10 seconds. Thus, although a single sniff may provide an initially useful odor "snapshot," longer-term sniff dynamics likely play important roles in other behaviorally-relevant olfactory tasks, such as matching anodor to a known odor object, gleaning precise concentration information, or evaluating complex mixtures. In this project we investigate several mechanistic hypotheses for how sniffing contributes to early coding of olfactory information in the olfactory bulb of adult mice. We focus specifically on pre- and post-synaptic cells in the olfactory bulb, which is the first step in olfactory processing. To access these cell types we use genetically-encoded calcium indicators (primarily GCaMP) coupled with targeted mutant mouse lines, allowing us to image calcium activity (a proxy for neural activity) in the pre-synaptic olfactory sensory neurons (OSNs) and the post-synaptic mitral cells (MCs). Our initial experiments in anesthetized animals using an artificial sniff paradigmhave found differences in how OSNs and MCs respond to changes in sniff frequency. We have found some evidence that response patterns decorrelate rapidly over time in MCs, but have not found evidence for this in OSNs, though more experiments are needed to clarify this question. These experiments show that OSNs and MCs respond differently to changes in sniff frequency. More broadly our results suggest that mammals engage in extended sniffing bouts to filter out background odorants and form unique odor percepts, beyond the information that they can glean from a single sniff alone.

134.6 ELDER, L.E.*; SEIBEL, B.A.; Yale University, University of South Floridia; *leanne.elder@yale.edu*

Transparency and Depth Effects on Metabolic Rates in Hyperiid Amphipods

This study sought to determine what environmental and ecological factors influence the rate of metabolism in marine amphipods. We examined species from a range of environments and with diverse morphologies. The mean metabolic rate for marine hyperiid amphipods was significantly lower in the deep-living clade Physosomata (1.54±0.67 µmol O2 $g^{-1}hr^{-1}$) than in the shallow-living clade Physocephalata (7.27±0.85 µmol O2 $g^{-1}hr^{-1}$). Within the clade Physocephalata metabolic rates of transparent species were significantly lower (3.74±0.88 µmol O2 $g^{-1}hr^{-1}$) than non-transparent species (12.00±1.38 µmol O2 $g^{-1}hr^{-1}$). The variation in metabolic rates is discussed in relation to environmental factors, including habitat depth and temperature as well as biotic factors such as transparency and body mass. Our results are consistent with the visual interactions hypothesis, which postulates that decreasing selection for locomotory capacity (by transparency or living permanently below the photic zone) limits predator-prey detection distance among visually oriented organisms and allows for reduced energy expenditure for locomotion. The use of gelatinous zooplankton as substrate, food or protection will also be discussed.

20.7 ELDERBROCK, EK*; SMALL, TW; SCHOECH, SJ; University of Memphis; *kldrbrck@memphis.edu*

Nestling Growth and Behavior Linked to Future Physiological Phenotype of Florida Scrub-jays

Different behavioral and physiological phenotypes that may impact the fitness of an individual exist within populations across taxa. These individual differences are often repeatable across the lifetime of an individual. In our study species, the Florida scrub-jay (*Aphelocoma coerulescens*), repeatable, long-term physiological phenotypes (high to low corticosterone response) impact reproductive success and survival, although in opposite directions for males and females. It remains unclear when and how these phenotypes develop, although evidence suggests that it occurs early in development, and that early exposure to environmental factors shape phenotypes to match the conditions an individual experiences. In this study we investigated the hypothesis that the adult phenotype is established before or during early development by monitoring individual Florida scrub-jays over the long-term (nestling through adulthood). We monitored nestling mass at hatch, growth and begging rate across the nestling period, as well as an individual's physiological stress response at 11 days of age. Additionally, we assessed all individuals' physiological stress responsiveness (i.e., corticosterone response to capture and handling) at 1 year of age. Our results suggest the phenotype is established early on in development, as mass within a few hours of hatching *predicted* an individual's future stress response. We also found that begging rate was correlated with adult corticosterone but the direction of the relationship changed as the individual aged. Further, nestling mass at hatching and begging rates were correlated in males only, suggesting a different developmental strategy for the sexes. These results reveal that the physiological phenotype of an individual is established early on in life, but that males and females differ early in development.

P2.84 ELKINS, EA*; LEMA, SC; California Polytechnic State Univ., San Luis Obispo; *slema@calpoly.edu*

Identification of a vasopressinase/oxytocinase-like LNPEP enzyme in a teleost fish

Mammalian leucyl-cystinyl aminopeptidase (LNPEP) - also as placental leucine aminopeptidase (P-LAP), insulin-regulated aminopeptidase (IRAP), vasopressinase, and oxytocinase - is a membrane-bound zinc dependent metalloexopeptidase enzyme that inactivates cyclic polypeptides including nonapeptide hormones of the vasopressin/oxytocin family. LNPEP activity plays a key role in the clearance of oxytocin during pregnancy in humans, and changes in renal LNPEP expression have been implicated as a mechanism of negative feedback for vasopressin's effects on renal water resorption. The evolutionary diversity and function of LNPEP in other vertebrate classes, however, remains unknown, even though nonapeptides of the vasopressin/oxytocin family have been studied extensively in the regulation of hydromineral balance and social behaviors in many non-mammalian taxa. Here, we isolated and sequenced a full length cDNA of 3,376 bps for a LNPEP-like enzyme from the ovarian tissue of the Amargosa pupfish *Cyprinodon nevadensis amargosae*. This pupfish inhabits in a remote desert river in the Death Valley region of California, USA, and has been studied for the effects of the teleost nonapeptide arginine vasotocin (AVT) on behavior and osmoregulation. The isolated cDNA encodes 1,033 amino acids and shares 62% residue identity with a putative LNPEP enzyme from zebrafish (*Danio rerio*) and 50% with LNPEP isoform 1 of humans. The tissue distribution of *lnpep* mRNAs in *C. n. amargosae* is being determined. As an initial step toward evaluating whether variation in brain LNPEP expression may link to social behavior, we also are exploring patterns of hypothalamic *lnpep* mRNA expression relative to the aggressive behavior and social rank of male and female pupfish.

76.2 ELLIOTT, KH; McGill University; *kyle.elliott@mcgill.ca*
Do wild seabirds show senescence?
The "rate of living" theory suggests a tradeoff between metabolism and survival and is supported by inverse correlations between metabolic rate and survival rates. Charadriiform seabirds are exceptions to this pattern because they live exceptionally long despite having sustained high metabolic rates. We investigate the tradeoff between metabolic rate and survival in Thick-billed Murres (Uria lomvia). Reproductive success increased with age between 7-11 years of age, before leveling off, with experience being a better predictor for reproductive success than age during the first 12 years of life. Reproductive success was lower during the final year of life compared to previous years and baseline cort higher, suggesting that death may be related to health effects evident in the last year of life. Hematocrit and metabolic rate appeared to decrease linearly with age, perhaps as a strategic adjustment to reduce the effect of heart disease in old age. Foraging ability appeared to be independent of age. When foraging conditions were experimentally worsened, time spent at the colony increased with age, with 33% of the youngest birds abandoning altogether. Furthermore, cort response levels to handling were higher in younger birds. We concluded that young birds were "prudent parents", and willing to sacrifice future reproductive success for current offspring leading to an increase in reproductive success with age, while old murres showed signs of deteriorating health when 20-25 years.

51.1 ELSHAFIE, SJ; Univ. of California, Berkeley; *selshafie@berkeley.edu*
Can We Infer the Ecology of Fossil Lizard Groups Using Extant Variables and Our Knowledge of Past Climate Change?
Ecology broadly correlates with morphology, climate, and environment in extant reptiles. But how specific variables correlate with ecology, particularly against changing climatic conditions through time, has not yet been tested. In this study, I ask whether specific features of extinct lizards and their environments are correlated with known associations in extant lizards of morphological traits, climate, habitat, and dietary and thermal ecology. I investigated the fossil record of North American anguid lizards, which were abundant through the Paleogene in the Western Interior basins. This group includes large forms (skull length ≤ 125 mm), with unknown ecological affinities, restricted to the Eocene. In a prior study, I estimated snout-vent length (SVL) from skull material for large Eocene anguids using extant analogous taxa, and found that anguid body size changes track climatic changes through the Eocene. For this study, I surveyed all extant lizard clades for suitable ecological analogues to large Eocene anguids based on morphological variables, including body size and dentition, as well as climatic and environmental context known from other proxies. *Xenosaurus* and *Heloderma* (Anguimorpha) scored highest for similarity in morphology and environmental context to large Eocene anguids. These results suggest that these lizards were saxicolous, thermoconforming insectivores living in closed tropical forests in the early Eocene. Late Eocene anguids were also insectivorous, but their thermal ecology remains unclear. Future work will integrate independent lines of evidence from the environmental context of cooling and aridification in the late Eocene to test for factors that contributed to the decline of large-bodied anguids by the Oligocene.

116.2 EMBERTS, Z*; MILLER, CW; KIEHL, D; ST. MARY, CM; University of Florida; *emberts@ufl.edu*
Beyond escaping predation: autotomy can reduce the survival cost of injury
Autotomy, self-controlled limb loss, is an extreme trait observed throughout the animal kingdom; lizards can drop their tails, crabs can drop their claws, and crickets can release their legs. These repeated evolutionary origins suggest that autotomy is adaptive. Yet, it remains unclear what selective pressures promote and maintain this extreme trait. While multiple adaptive hypotheses exist, research has generally focused on autotomy's adaptive value as a form of predator escape. However, autotomy could also be selected to reduce the cost of an injured limb. Previously, this alternative hypothesis has been challenging to directly test because when an injury occurs on an autotomizable limb that limb is almost always dropped. However, we have recently identified a species, *Narnia femorata* (Insecta: Hemiptera: Coreidae), where some individuals autotomize limbs in response to injury, but some do not. This natural variation allowed us to investigate both the survival costs of retaining an injured limb and the benefits of autotomizing it. In this study, we find a positive association between autotomizing injured limbs and survival, providing evidence of a new, and likely widespread, benefit of autotomy — reducing the cost of injury.

36.3 EMERLING, CA; University of California, Berkeley; *caemerling@berkeley.edu*
Genomic Evidence for a Crocodylian Nocturnal Bottleneck and Reinvention of Trichromatic Color Vision in Crocodiles
Vertebrate color vision has evolved through the modification of five ancestral visual opsin proteins via gene duplication, loss and shifts in spectral sensitivity. While many vertebrates, including mammals, birds and fishes, have had their visual opsin repertoires studied in great detail, crocodylians have largely been neglected. Of particular significance is a purported nocturnal bottleneck experienced by stem crocodylians, predicted on the basis of comparative eye anatomy. A long period of dim-light adaptation has also been hypothesized for mammals, undergirded by ocular anatomy and the loss of light-dependent genes. Here I examine the genomic basis for color vision in four species of crocodylians, and found that they experienced a reduction in their color discrimination capacity after their divergence from birds. Based on the opsin sequences present in their genomes and previous measurements of crocodylian cones, I provide evidence that crocodylians have co-opted the rod opsin (RH1) for cone function. This further implies that some crocodylians have reinvented trichromatic color vision in a novel way, analogous to several primate lineages. The loss of visual opsins is also associated with the loss of non-visual opsins and genes associated with protection from ultraviolet light, many of which were lost in parallel in mammals. Two genes, encoding parietopsin and parapinopsin, were additionally inactivated in birds and turtles, likely co-occurring with the loss of the parietal eye in these lineages.

S3.1 EMMONS, S.W.; Albert Einstein College of Medicine; *scott.emmons@einstein.yu.edu*

Neural circuitry that mediates behavior governing the tradeoffs between survival and reproduction in Caenorhabditis elegans

Though C. elegans is a tiny, 1mm, nematode with fewer than 400 neurons in its nervous system, it nevertheless faces the same challenges of finding resources, staying safe, and reproducing that all animals do. Uniquely in C. elegans, it is possible to completely define the neural circuitry that governs the decision-making required for successfully navigating this set of goals. Well-fed C. elegans males will prioritize finding a mate over remaining with a food source and will wander and search around their environment. Wandering away from a food source that lacks mates is stimulated by male-specific sensory neurons in the tail copulatory apparatus, which communicate to the motor system via male-specific interneurons, as well as by signals from the gonad. Male sexual drive, including mate-searching behavior, is stimulated by an oxytocin-related neuropeptide and a PDF (pigment-dispersing factor) neuropeptide. Receptors for these peptides are expressed by multiple neurons throughout the nervous system. Male-specific interneurons in the head dictate associative learning preferences of the male. When a normally attractive cue, salt, is presented together with an aversive cue, starvation, both males and hermaphrodites (females), adults and juveniles, learn to avoid salt. But for sexually-mature males, if mating partners are also present when the two conflicting cues are presented, the sex cue trumps the starvation signal and salt remains attractive. These studies represent just the beginning of a holistic understanding of how drives, environmental cues, and internal physiology are integrated for an individual's best advantage in the game of survival and reproduction.

112.4 ENBODY, E/D*; LANTZ, S/M; KARUBIAN, J; Tulane University; *eenbody@tulane.edu*

Males and females differ in the production of plumage ornaments in two tropical passerine birds

Visual ornaments have evolved in a wide range of taxa to convey information about quality and condition. Ornamentation can be found in both sexes in birds, and comparative work shows that sexual dichromatism can arise due to changes in both male and female colors. However, many questions remain about the underlying mechanisms of ornament evolution and how these may act to promote or constrain evolutionary pattern and tempo. We contrast the anatomical basis for variation in a plumage-based signal in three lineages of *Malurus* fairywrens (family Maluridae) using a combination of photospectroscopy and electron microscopy. We focus on melanin-based color in two subspecies of *Malurus alboscapulatus* (WSFW: White-shouldered Fairywren), that differ in degree of female ornamentation, and *Malurus melanocephalus* (RBFW: Red-backed Fairywren) that exhibits within year variation in male ornamentation. We leveraged these patterns of variation to assess how changes in feather morphology mediate changes in visual signal expression within and among sexes of these two closely related species. First, we ask how males and females differ in color and feather structure and compare ornamented and unornamented female in the WSFW. Next, we assess mechanisms of production in RBFW, but instead by focusing on comparing ornamented and unornamented males to unornamented females. Our over-arching, null hypothesis was that ornamentation is produced through similar changes in barbule density and fine scale arrangement of melanin in barbules across all sexes and species. We find that females produce an ornament unique from males that corresponds to differences in underlying feather structure characteristics. In contrast, in the RBFW we found similarity between unornamented males and unornamented females in color and feather structure.

P2.135 ENGELN, KA; Reed College; *kimberley.engeln@wsu.edu*

Integrated Physiological and Behavioral Phenotypes of Maternal Fitness

Maternal care behavior is plastically adjusted based on external and internal cues. Differences in maternal phenotypes can be observed between laboratory raised animals and their wild-raised conspecifics, raising the question of how environmental stimuli and physiological mechanisms integrate to produce adequate maternal behavior. These inextricably linked networks have often been studied in isolation, but a thorough investigation of maternal phenotypes requires an investigation of the interplay between internal and external sources that affect successful reproduction. Using an integrated comparative approach, this study examines physiological and behavioral differences between two lab-raised and wild-raised stocks of the brooding cichlid fish Astatotilapia burtoni, which demonstrate divergent patterns of maternal investment. Gene expression patterns were measured using microarrays and hormones were quantified with enzyme-linked immunosorbent assays, and were then compared between stocks in conjunction with recorded morphological and behavioral data. Results indicate significant differences in rates of filial cannibalism and weight regulation between the two stocks, revealing a characteristic phenotype between good and inept brooders. These findings contribute to the limited compendium on the neural mechanisms which influence maternal care behaviors.

P2.81.5 ENGLEN, K*; RENN, SCP; O'ROURKE, CF; Washington state University, Vancouver,, Reed College; *kimberley.engeln@wsu.edu*

Amalgamating Metabolic Regulation and Maternal Care in an African Cichlid fish.

Maternal care is an essential adaptive social behavior for many species, yet the underlying neural mechanisms have largely been addressed in mammalian systems. A new mother's brain undergoes a fundamental transformation that shapes maternal behavior. We study maternal mouth-brooding in the cichlid fish Astatotilapia burtoni. In this independently-evolved instance of robust care, the neural circuits regulating maternal behavior are inextricably linked with the feeding circuits to allow voluntary starvation despite significant loss of body mass. Maternal mouth-brooding offers an extreme example of parent-offspring conflict in a tractable system for careful mechanistic studies. We use two different A. burtoni fish stocks, one an inbred labstock inadvertently artificially selected for rapid reproduction and low maternal investment and the other a recently collected wild stock that displays a rich repertoire of maternal care and resistance to starvation induced loss of body condition. We measure behavior, morphological changes, hormone profiles and gene expression patterns throughout the brooding cycle. We focus on two important transitions, spawning and release of fry, in order to identify key mechanisms that underlie the good mother phenotype in the wildstock females.

56.4 ENGLISH, PA*; NOCERA, JJ; GREEN, DJ; Simon Fraser University, Burnaby, B.C. Canada, University of New Brunswick, Fredericton, N.B. Canada; *penglish@sfu.ca*

Of moths and moon: complicated phenological mismatch in a nocturnal aerial insectivore

The foraging style and long annual migrations of aerially insectivorous birds may make them particularly sensitive to changes in seasonal phenology and weather extremes. Nocturnal aerial insectivores, like the whip-poor-will *Antrostomus vociferous*, face the additional challenge of only foraging during twilight periods, or when adequate moonlight is available. We assessed daily nest survival and annual productivity in relation to weather, seasonal changes in the abundance of night-flying insects, and moon phase. Nest survival through incubation was 40% across all years. Nestling survival to 15 days of age dropped from 91% in 2011 to 42% in 2012 and rose moderately to 67% in 2013. Daily nestling survival was lowest in the middle of the breeding season, and higher on rainy days or when moth abundance was high. Moonlight was only retained in a top model when combined with moth abundance. Minimum adult male annual survival was 63% (46% in 2012 and 89% in 2013). When compared between years, we find hatch dates track earlier peak insect abundance in 2012, but food availability averaged much lower and was largely asynchronous with periods of peak moonlight. These factors may explain the lower nest survival rates, but were partially overcome by more nesting attempts (fledglings/pair: 1.56 in 2011, 1.22 in 2012). Our results support the unique potential for phenological changes in insect abundance to interact with both weather and moonlight to influence productivity of lunarphilic nocturnal insectivores.

85.4 ENSMINGER, D*; LANGKILDE, T; OWEN, D; MACLEOD, K; SHERIFF, M; Pennsylvania State University; *dls_david@yahoo.com*

The Effect of Maternal Stress on Maternal Behavior and Offspring Morphology in Sceloporus undulatus

The physiological impact of stress and its adaptive potential are areas of interest in the fields of ecology and biology, as we are in a time of increased anthropomorphically induced perturbations. In addition to mediating the link between environmental variability and organismal plasticity, such as changes in behavior and fitness, GCs are also a mechanistic translator between mothers and their offspring. We tested the hypothesis that chronic stress will alter maternal behavior and body condition as well as offspring morphology. We treated wild caught gravid female eastern fence lizards (*Sceloporus undulatus*) daily with transdermal applications of GCs at an ecologically relevant dose (GC response similar to a fire ant attack) from capture to ovoposition. Eggs were collected and incubated until hatching. We found that stressed females basked less, had higher blood glucose, and lost significantly more weight during gestation compared to controls. Maternal stress did not affect egg morphology or hatchling mass, but did increase hatchling snout-vent length. These results suggest that stress experienced by a gravid female has ecologically relevant effects on hatchling morphology which may be mediated by changes in the behavior, metabolism, and egg allocation of the gravid female.

73.2 ENZOR, LA*; MOSO, E; HANKINS, C; BARRON, MG; US Environmental Protection Agency; *enzor.laura@epa.gov*

The Effects of Elevated pCO_2, Hypoxia and Temperature on Larval Sheepshead minnow, Cyprinodon variegatus: How much stress is too much?

Estuarine fish are acclimated to living in an environment with rapid and frequent changes in temperature, salinity, pH, and dissolved oxygen (DO) levels; the physiology of these organisms is well suited to cope with extreme thermal, hypercapnic, and hypoxic stress. While the adverse effects of low dissolved oxygen levels on estuarine fish has been well-documented, the interaction between low DO and elevated pCO_2 is not well understood. There is some evidence that low DO and elevated pCO_2 interact antagonistically, however little information exists on how projected changes of pCO_2 levels in near-shore waters may affect estuarine species, and how these changes may specifically interact with dissolved oxygen and temperature. We explored the survivability of 7-day post fertilization sheepshead minnow, *Cyprinodon variegatus*, using short term exposure to the combined effects of elevated pCO_2 (~1300 µatm; IPCC RCP 8.5) and low dissolved oxygen levels (~2 mg/L). Additionally, we determined if the susceptibility of these fish to elevated pCO_2 and low DO was influenced by increases in temperature from 27.5°C to 35°C. Results from this study and future studies will be used to identify estuarine species and lifestages sensitive to the combined effects of elevated pCO_2 and low dissolved oxygen.

70.2 ERB, V*; LOLAVAR, A; WYNEKEN, J; Florida Atlantic University; *verb2015@fau.edu*

The Role of Weather and Sand Moisture in Shaping Loggerhead Sea Turtle (Caretta caretta) Neonate Growth

Many environmental variables affect the early development of incubating eggs. The effects of temperature on loggerhead sea turtle (*Caretta caretta*) eggs are often considered in understanding developmental factors such as incubation duration and sex ratios. Until recently, the role of sand moisture has been studied little, but recent work showed that increased moisture in the field may affect sexual differentiation and embryonic development. We hypothesize that loggerhead neonate growth rate may also be impacted by variable moisture. Growth rates and emergence success for natural (*in situ*) and experimental nests were studied during the 2015 nesting season. Each nest was classified incubating earlier in the nesting season (hot dry conditions) and later in the nesting season (hot wet conditions). In an experimental field study we divided clutches in half and reburied them. One half-clutch of the pair received ambient rainfall ("dry") while the other half-clutch received ambient rainfall plus daily watering ("wet"). Data loggers monitored incubation temperatures. Upon emerging, turtles were raised in the lab for several months until reaching ~120 g. Weekly mass, straight carapace length (SCL), straight carapace width (SCW), and body depth (BD) measurements were taken and growth/day calculated. Mann-Whitney U tests compared median growth rate for dry versus wet neonates for natural and experimental nests. Turtles from wet nests grew faster in SCL and mass but not SCW and BD. Emergence success was higher for wet nests. Given concerns about increasing temperature and shifting rainfall patterns along Florida coastline due to climatic change these results highlight how varying weather patterns may have otherwise cryptic effects on marine turtles.

129.2 ERICKSON, GM*; KUHN-HENDRICKS, SM; SIDEBOTTOM, MA; CURRY, JF; ZENG, G; NORELL, MA; KRICK, BA; Florida State University, Tallahassee, Lehigh University, Bethlehem, Lehigh University, Bethlehem, American Museum of Natural History, New York; *gerickson@bio.fsu.edu*
Wavy Enamel in Hadrosaurid Dinosaurs with Grinding Dentitions Functioned to Limit Fracture Damage through Energy-Robbing Crack Deflection and Channeling
Reptiles rarely approached the biomechanical sophistication of feeding or dietary diversity seen in mammals. Their teeth are typically non-occluding structures with simplistic architecture. Conversely, most mammals possess teeth that are drawn across one another during mastication, self-wear to their functional morphology and are composed of prismatic enamel. Among the most sophisticated prism architectures is the modified radial enamel (MRE) of grazing ungulates whose coarse tooth surfaces enable the grinding of tough, abrasive laden plant matter. MRE conveys exceptional fracture toughness and controlled fracture propagation. Hadrosaurid dinosaurs independently evolved self-wearing grinding dentitions and possess wavy enamel (WE), composed of folded layers of hydroxyapatite crystals. We tested the hypothesis that WE served an analogous biomechanical role to MRE. We: 1) tribologically modeled the effects of enamel fracture on hadrosaurid occlusal surfaces; 2) introduced enamel fractures to teeth from hadrosaurids, archosaurian outgroups, and horse and bison, 3) documented crack patterns; and 4) contrasted the results with regard to occlusal morphology and dietary inferences. Enamel removal leads to aberrant self-wear to hadrosaurid chewing pavements. Non-wavy enamels show isotropic fracture patterns and catastrophic enamel shell damage. WE limits damage to the enamel crests through energy-robbing crack deflection at kinks in the enamel fabrics and channeling perpendicular to the enamel-dentine junction like the teeth of grinding ungulates.

78.4 ERN, R*; ESBAUGH, AJ; University of Texas at Austin, USA; *rasmus@ern.dk*
Temperature, oxygen, metabolism and upper thermal niche boundaries of water-breathing ectotherms
Temperature-induced limitations on the capacity of the cardiorespiratory system to transport oxygen from the environment to the tissues have long been regarded as the principal determinant of the upper thermal limits of water-breathing ectotherms. Consequently, the upper thermal niche boundaries of these species are considered highly sensitive to aquatic hypoxia and other environmental stressors that constrain cardiorespiratory performance. However, the generality of this dogma has been questioned as some species have been found to maintain their cardiorespiratory performance at high temperatures. We recently proposed a novel metric for characterizing the oxygen-dependence of the upper thermal limits, and assessing the synergistic effects of environmental stressors on the thermal tolerance of cardiorespiratory performance; the oxygen limit for thermal tolerance (PCT_{max}), which is the water oxygen tension (P_wO_2) where an organism's upper thermal limit (CT_{max}) starts to decline. Determining PCT_{max} in a number of tropical, temperate and polar aquatic ectotherms; including black-axil chromis, red drum, lumpfish and antarctic krill, we found that only in the antarctic krill were the upper thermal limits determined by insufficient tissue oxygen supply. In black-axil chromis, red drum and lump fish, the upper thermal limits were maintained over a wide range of water oxygen levels. Aquatic hypoxia should therefore have little impact on the upper thermal niche boundaries of these tropical and temperate species. In light of these findings we propose a framework for characterising the relationship between temperature, oxygen, metabolism and upper thermal niche boundaries of water-breathing ectotherms.

115.4 ERNST, DK*; WILSTERMAN, K; KUMARAVEL, J; BENTLEY, GE; Univ. of San Francisco, Univ. of California, Berkeley; *dernst@usfca.edu*
Ovarian GnIH expression and steroidogenesis in response to acute stress in an opportunistically-breeding songbird
Gonadotropin-inhibitory hormone (GnIH) is synthesized in the hypothalamus and gonads and can influence all levels of the reproductive axis. In the gonads, GnIH can down-regulate expression of steroidogenic enzymes, thereby reducing production of sex steroids. Corticosterone and metabolic stress can induce GnIH expression in the gonads in vitro, suggesting that GnIH may mediate stress-induced decreases in circulating sex steroids. Previously, we found that acute restraint stress increased expression of GnIH in zebra finch testes. In the present study, we hypothesized that GnIH in the ovaries would respond to acute restraint stress, but that the response would differ according to the reproductive status of the female (hierarchical vs. non-hierarchical ovarian follicles). To test this, we collected ovaries in different stages of development from females immediately after capture or following 60 minutes of restraint. Restraint significantly increased plasma corticosterone and average expression of GnIH across the ovary. The increase in GnIH expression appeared to be driven by expression in small white (SW) follicles. GnIH expression in this follicle type increased significantly with restraint stress but, within restrained females, did not differ between females with a hierarchical vs. non-hierarchical ovary. Expression of steroidogenic acute regulatory (StAR) protein did not differ significantly with restraint stress. Other steroidogenic enzymes (3BHSD, 17BHSD, aromatase) are potential targets for regulation by stress and GnIH. Further research will address whether GnIH in the SW follicles is acting in an autocrine or paracrine manner to control steroidogenesis in adjacent ovarian follicles.

P2.171 ERNST, DA*; LOHMANN, KJ; Univ. of North Carolina, Chapel Hill; *dernst@live.unc.edu*
Repulsive Accommodations: Caribbean Spiny Lobsters Avoid Dens with Strong Magnets
The Caribbean spiny lobster (*Panulirus argus*) is known for its remarkable ability to detect and utilize the geomagnetic field for navigation. Recent studies found that a brief, strong magnetic pulse had a significant effect on lobster orientation. While it is clear that lobsters respond to Earth-strength magnetic fields and strong magnetic pulses, whether lobsters respond to a static, strong field is not known. As a first attempt to determine the effects of a static, strong magnetic field on lobster behavior, we tested lobsters in a simple two-choice preference experiment. Lobsters were released in the center of a rectangular, seawater-filled arena and allowed 15 minutes to choose one of two artificial dens on either end of the arena. Each den was equipped with a sealed PVC capsule containing either a strong neodymium magnet (magnet den) or a non-magnetic weight (control den). The positions of the magnet and weight were alternated between the two dens for each trial. We found that significantly more lobsters chose the control den, indicating that lobsters avoided the strong magnetic field associated with the magnet den. Interestingly, lobsters that took refuge in the magnet den were significantly smaller than those that inhabited the control den. These findings provide further support for magnetic field detection in spiny lobsters and suggest that strong magnetic fields might influence lobster behavior in the natural environment.

89.1 ESBAUGH, AJ; University of Texas at Austin, Marine Science Institute; *a.esbaugh@austin.utexas.edu*

Physiological insights into ocean acidification and resilience from an estuarine-dependent teleost

Rising atmospheric carbon dioxide levels are resulting in dramatic changes to oceanic carbonate chemistry, collectively known as ocean acidification (OA). The effects of OA are hypothesized to be wide ranging as the rate of environmental degradation is likely to outpace the ability of organisms to evolve. Instead, species resilience may depend largely on pre-existing physiological traits and phenotypic plasticity. Interestingly, many marine fish species utilize estuaries at various points of their lifecycle. These habitats have seasonally variable CO_2 levels that routinely exceed future predictions, which leads to the hypothesis that these species may have pre-existing physiological traits that can defend against OA. Here we will use the economically important red drum as an estuarine-dependent model teleost to explore various aspects of acid-base physiology within the framework of OA. Specifically, we will discuss the implications of OA to acid-base physiology and the capacity of red drum to offset OA through plastic and non-plastic mechanisms. Furthermore, we will discuss new insights into the role of ventilation in defending against respiratory acidosis in marine fish, while also exploring the potential of plastic and non-plastic responses to result in deleterious physiological trade-offs at the whole animal level.

P1.58 ESCALANTE, I*; MACHADO, G; CHELINI, MC; CLASSEN-RODRIGUEZ, L; FOWLER-FINN, KD; University of California Berkeley, Universidade de Sao Paulo, University of Nebraska Lincoln, University of Puerto Rico Rio Piedras, Saint Louis University; *iescalante@berkeley.edu*

Patterns of autotomy in daddy long-legs: the influence of the environment, species, sex and leg length

Many animals voluntarily release their legs and/or other appendages during encounters with potential predators. Many life-history traits may influence which body parts are lost. However, comprehensive surveys of such traits in the field are rare. We aimed to describe the frequency of leg loss in 16 species from 6 genera of Scleresomatidae daddy long-legs (Arachnida: Opiliones) across the Americas, as well as elucidate potential morphological, behavioral and ecological factors affecting the patterns of leg loss (autotomy). Across species, the percentage of autotomized individuals was generally high but variable with some populations showing autotomy rates of up to 60%. In general, species from temperate zones showed lower autotomy rates. We suggest that this pattern is explained by higher predation pressure in tropical regions. Among sexes we also found different patterns of leg loss even among the same genera, potentially associated with life history differences between species. In one species of *Prionostemma* from Costa Rica females were larger than males, and their legs were longer, with an interesting exception: the length of the antenniform legs (the second pair) did not differ between sexes. Males having longer legs could be related with finding food and mates more efficiently, and even for courtship behavior purposes. However, this idea remains untested. Finally, we found differences in the patterns loss between leg types. We found that the second pair of legs were lost three times more frequently than expected by chance in all 16 species, possibly due to its longer length and/or behaviors associated with exploration as these arachnids use legs II as sensory organs to probe the environment.

P3.31 ESMAEILI KHARYEKI, M; REZAEI, M; BORDENAVE-JUCHEREAU, S; MOTAMEDZADEGAN, A; KHODABANDEH, S*; Univ. of Tarbiat Modares (TMU), TMU, Univ. of La Rochelle, Sari University; *surp78@gmail.com*

Investigation of antidiabetic and antioxidant activities of skipjack tuna head protein hydrolysate

Diabetes mellitus is an important metabolic disturbance and a major health problem worldwide. Inhibition of DPP-IV may improve glycemic control in diabetics by preventing the quick breakdown and there by prolonging the physiological action of incretin hormones. Furthermore, improving the antioxidant system in diabetic patients can prevent the occurrence of secondary disease caused by oxidative stress in these patients. Therefore, in order to optimum utilization of fish processing factories waste, the skipjack tuna head was hydrolyzed with alcalase enzyme for 4 hours. The effect of hydrolysis time (15, 60, 120 and 240 minutes) on the degree of hydrolysis was investigated. Also, the DPP-IV inhibitory activity, DPPH and ABTS radical scavenging activity and reducing power of hydrolysate were measured. According to the results, increasing the duration of hydrolysis led to significant increase in the degree of hydrolysis ($p \leq 0.05$), and following 4 hours it was about 45%.The skipjack tuna head protein hydrolysate has exhibited bioactive properties in a concentration dependent manner such a way that increasing the protein concentration leads to a significant increase ($p \leq 0.05$) in bioactive properties of hydrolysate. The IC50 values of protein hydrolysate for DPP-IV inhibition and DPPH and ABTS radical scavenging activities was 1.016±0.02 mg/ml, 0.297±0.015 mg/ml and 2.19±0.34 mg/ml, respectively. Also the reducing power of hydrolysate, which reports as absorption at 700 nm, was 0.176±0.002 in 2.5 mg/ml protein concentration. Overall, according to the results, it can be concluded that skipjack tuna head protein hydrolysate has high in vitro antioxidant and antidiabetic activities and can be used as a food additive to enhance health level if additional research be conducted.

P3.236 ETNIER, SA*; QUILTER, LAS; LYONS, R; Butler University, Indianapolis, IN; *setnier@butler.edu*

Hind Foot Reversal in the Family Sciuridae

Head first descent from trees is a common attribute of most arboreal mammals, allowing an animal to see and evaluate potential dangers on the ground during descent. In order to engage their claws and muscles during head first descent, arboreal mammals typically depend on hind foot reversal (HFR), in which the extended hind limb plantarflexes and supinates such that the plantar surface can contact the support while the digits point skyward. While arboreality appears to be the ancestral condition for sciurids, the ankle modifications that permit HFR are a derived trait seen in modern tree squirrels that are specialized for arboreal locomotion. Although the mechanism of hind foot reversal in sciurids has been noted in the literature, no detailed measures of HFR have been reported. In this study, we quantified HFR in 5 sciurid species that varied in their level of arboreality. Specifically, we examined two arboreal species (Gray squirrel, *Sciurus carolinensis*; Fox squirrel, *Sciurus niger*), one semi-arboreal species (Eastern chipmunk, *Tamias striatus*) and two terrestrial species (Utah prairie dog, *Cynomys parvidens*; Marmot, *Marmota monax*). Prairie dogs had significantly lower plantarflexion and supination compared to other species, while the highly arboreal gray and fox squirrels were significantly higher in both measures. Chipmunks and marmots were similar to arboreal species with respect to plantarflexion but were intermediate in value with respect to supination. While marmots are classically considered terrestrial, they can climb trees and these results suggest they should more correctly be classified as semi-arboreal. The combination of significant plantarflexion coupled with intermediate supination may not permit full HFR, but the overall increased foot mobility may be a requirement to efficiently navigate both on the ground and in the trees.

P1.63 EUBANK, J*; EDDINGTON, SA; MUSCEDERE, ML; Hendrix College, Conway AR; *eubankaa@hendrix.edu*

Body Size, Task Specialization, and Olfactory Learning In Carpenter Ants (Camponotus americanus)

Polymorphism in social insect colonies is predicted to increase colony fitness by improving the efficiency of division of labor, although studies of polymorphic species have not always demonstrated this advantage. In our study we assessed the ability of carpenter ants of different body sizes to learn food-related odors, and investigated the link between learning ability and foraging performance. We showed that smaller *C. americanus* workers are better learners, and hypothesized that they would therefore forage more than larger nestmates. While foraging is not the only outside-nest task ants perform, we used outside-nest activity as a proxy for foraging effort. In lab-reared colony fragments, large workers were overrepresented outside the nest, contrary to our hypothesis. When lab colonies were placed in larger arenas and imaged so worker distance from the nest entrance could be quantified, we found some evidence that minors ranged farther from the nest entrance than majors, although worker distributions were highly variable and this pattern was not evident in most colonies. Preliminary field pitfall trapping confirmed that *C. americanus* are primarily nocturnal foragers, but the size distribution of the trapped workers included large individuals and was similar to that of our lab-reared colony fragments, demonstrating that larger individuals work outside the nest under natural conditions. Our results suggest that although small workers are more responsive to liquid food and better able to learn associations between odors and food rewards, they are not strongly overrepresented in the outside-nest worker force. Further work involving direct observations of foraging behavior *per se* will be necessary to determine if smaller *C. americanus* workers actually preferentially perform this task in nature.

69.2 EVANS, K*; WALTZ, B; TAGLIACOLLO, V; CHAKRABARTY, P; ALBERT, J; University of Louisiana at Lafayette, Louisiana State University; *kxe9300@louisiana.edu*

Modularity begets brachycephaly: Repeated patterns of neurocranial evolution in Neotropical electric fishes

The Neo-Darwinian view of adaptation by natural selection assumes that phenotypic variation is produced randomly with respect to function. However, developmental pathways are often buffered against the effects of mutations such that small changes in the timing of gene expression may generate non-random, functionally viable phenotypes. Here we explore the role of heterochrony in the production of ontogenetic variation and phylogenetic diversity in the neurocrania of Neotropical electric fishes (Gymnotiformes: Teleostei). We assess patterns of shape changes during growth and among adults of different species using landmark-based geometric morphometrics in an explicitly phylogenetic framework. We find the brachycephalic to dolichocephalic axis of neurocranial variance, broadly observed across many vertebrate groups, represents the largest component of shape variance (PC1) in development and evolution. We also find shape changes in the face and braincase regions are more integrated during growth in some taxa, and more modular in others, thereby suggesting tradeoffs in the developmental coordination of these two skull regions. These results suggest that neurocranial evolution in gymnotiform electric fishes is constrained by common genetic and developmental pathways present in all vertebrates, and that this biased production of variation has constrained the evolution of neurocranial morphology along lines of least developmental resistance.

S7.11 EXTAVOUR, Cassandra/G; Harvard University; *extavour@oeb.harvard.edu*

Development and Evolution of Arthropod Reproductive Systems

Reproduction is an essential element of the evolutionary process: it underlies the inheritance of traits, and trait variation determines the outcome of both adaptive and non-adaptive evolutionary change. The capacity of the reproductive system to produce viable offspring depends on a number of variables. These can include environmental factors such as nutritional quantity and quality, humidity, temperature, and altitude, and thus reproductive capacity is subject to a great degree of phenotypic plasticity. There are also aspects of reproductive capacity that are heritable, including the structure of the reductive organs, the control of gametogenesis, and the success of fertilization in the case of sexual reproduction. There is also, therefore, a significant genetic component that determines lifetime reproductive output. The combination of these many factors, and the clear contribution of reproduction to fitness, mean that reproductive systems offer exciting contributions to examine outstanding problems at the intersection of development, genetics, evolution and ecology. We will discuss the evolutionary variation, genetic control and ecological influence over one important component of arthropod reproductive systems, namely, the number of ovarioles found in insect ovaries. Ovarioles are individual egg-producing subunits found in all insect ovaries, and the number of ovarioles is a high-fidelity predictor of lifetime egg production for females of the genus Drosophila. We will discuss our findings of some of the genetic and ecological factors that can influence ovariole number in both laboratory-reared and wild-caught populations, and consider whether analogous ovarian structures exist across non-insect arthropods.

P1.14 FABIANO, J. N.*; HIGGINS, D.; ORTEGA, J.; PRECOPIO, L.; WATERS, J. S.; Providence College; *jfabiano@friars.providence.edu*

The pressure is on: modeling, design, and performance of circulatory pumps in physiology

One of the core principles of physiology is that organismal performance depends on the fluxes of many types of matter and energy. For most animal systems the dynamics of these flux rates depends on the structure and function of circulatory systems, making an understanding of these systems and their associated pumping mechanics of paramount importance in physiology education. As a way to learn first-hand about the design and performance of pumps in physiology, and in tribute to the memory and legacy of the Professor Steven Vogel (1940-2015), we spent a semester designing, building, and testing the performance of various physical models of animal circulatory systems. This semester-long effort was a minimally guided, open-inquiry, laboratory exercise involving four groups of students concurrently taking human physiology and also engaged in additional, more typical, laboratory exercises. Student groups built models of branching circulatory systems, multi-chambered hearts, and both valved and valveless displacement pumps. While the open-inquiry structure of the labs offered students a wide degree of independence and lead to many serendipitous discoveries, it was proposed that additional structure and guidance would help future student groups more efficiently accomplish their goals.

129.1 FABRE, A.-C.*; DUMONT, M.; WALL, C.E.; BREWER, D.; EHMKE, E.; WELSER, K.; DUMONT, E.; GODFREY, L.; HERREL, A.; UMR7179 CNRS/MNHN, 55 rue Buffon, 75005 Paris, France, psala Universitet, Evolutionsbiologiskt Centrum EBC Norbyv. 18A, 752 36 Uppsala, Duke University, Evolutionary Anthropology, 27708 Durham, NC, USA, Duke Lemur Center, 3705 Erwin Road, Durham, NC 27705, UMass Amherst, Biology, Amherst, MA 01002, UMass Amherst, Anthropology, Amherst, MA 01002; *fabreac@gmail.com*

Geometric morphometric approaches to inferring bite force and diet in extinct strepsirrhines.

The cranial system in mammals is highly constrained. Feeding forces, phylogeny, and the need to protect the brain and sensory organs are all important factors driving the evolution of the shape of the skull. Here, we explore relationships between bite force, cranial, and mandibular shape to infer the dietary ecology and bite force in two extinct species of strepsirrhines. We collected data on molar and incisor bite forces and analyzed cranial and mandible shape using 3D geometric morphometric approaches for 18 species of strepsirrhines that differ in feeding ecology. In addition we use data on mandibular shape to infer the diet of two extinct species, *Archaeolemur edwardsi* and *Hadropithecus stenognathus* and use the observed co-variation between bite force and mandible shape in extant taxa to infer bite forces in these taxa. Our results show that bite forces vary across species with dietary specialists differing in bite force, cranial shape, and mandibular shape. The covariation between bite force and mandibular shape was strong and based on these data we inferred molar bite forces of 212 and 237 in *A. edwardsi* and *H. stenognathus* respectively. Finally, mandibular shape data demonstrate that both species were folivores supporting the most recent stable isotope data for these species. [supported by NSF-BCS-1062239 to CEW]

46.2 FAGGIONATO, D; PAIRETT, AN; SERB, JM*; Iowa State Univ.; *serb@iastate.edu*

Expression and Spectral Analysis of Eleven Opsins Reveals Astonishing Photochemical Diversity in the Scallop Argopecten irradians (Mollusca: Bivalvia)

Despite having complex mirror eyes and showing mantle shadow response, the molecular details of scallop light perception have been poorly studied. To unravel the molecular components responsible for light perception in scallop, our lab has assembled transcriptomes from the eyes and mantle tissue of *Argopecten irradians*. Among other components of the phototransduction pathway, we have identified eleven complete and one incomplete opsin gene sequences from the scallop. We present a detailed molecular and functional characterization of these opsins. All twelve opsins were phylogenetically placed into five major opsin clades, including neuropsin, Go- and Gq-protein coupled opsins, retinochrome, and xenopsin (Gx). Then using a combination of genes isolated from RNA and synthetic genes, we successfully expressed eleven opsins in vitro. Spectral analysis of opsin proteins demonstrates that all are light sensitive. Of the eleven opsins, we quantified the maximum absorbance (lambda max) for four proteins. Six (4 Gq, 1 Go, 1 Gx) opsins form a bistable pigment that can convert its retinal chromophore from the 11-cis to the all trans conformation multiple times. Surprisingly, we found dramatically diverse photochemical properties among the three xenopsins, where two are monostable with a metastate that is blueshifted in a similar manner to vertebrate visual Gt ciliary opsin, while the other is bistable and has a metastate that is redshifted similarly to metamelanopsin. These data show that the diversity of photochemistry for xenopsins/ciliary opsins has been underestimated and is more complex than what can be inferred phylogenetically and open new question on the evolutionary origins of monostable and bistable pigments and their biological role in living systems calling for more functional studies of opsins.

P2.110 FALSO, PG*; MARSHALL, LV; GUSTAFSON, KL; FALSO, MS; SHIDEMANTLE, GI; ZAJAC, JM; Slippery Rock University; *paul.falso@sru.edu*

Stress Physiology in a Model Amphibian Following Exposure to a Neonicotinoid Pesticide

Amphibians are exquisitely sensitive to environmental conditions and have experienced widespread and rapid declines in recent decades due to global change. Amphibians in altered habitats may be subject to multiple anthropogenic stressors that have dramatic implications for population maintenance. Aquatic contaminants are ubiquitous and likely present a long-term challenge to amphibian health. Previous studies have documented altered stress hormone (corticosterone) levels in amphibians caused by contaminant exposure in both laboratory and field settings. In addition to primary effects on metabolism, altered corticosterone regulation may in turn influence diverse processes such as development, immunity, reproduction, and behavior. Here, we investigate the effects of the most important insect-killing systemic pesticide class, the neonicotinoids, on amphibian corticosterone regulation and associated physiology. Imidacloprid is the most commonly used neonicotinoid pesticide and has been found to contaminate aquatic environments yet little information is available on its effects in exposed aquatic animals. This study assessed the effects of imidacloprid exposure in the African clawed frog (*Xenopus laevis*) as a model for wild populations. Adult male (*X. laevis*) were exposed to environmentally relevant concentrations of imidacloprid by immersion for 48 days. Plasma corticosterone, metabolic, and immune endpoints were examined from samples collected under baseline and handling-stressed conditions. This study provides insight into the effects of a highly used, yet not extensively studied, aquatic contaminant on amphibian physiology.

P3.138 FANG, IJ*; WALTERS, LJ; Univ. of Central Florida; *iris.fang@knights.ucf.edu*

Breakpoint: Understanding how bioeroders impact intertidal oyster restoration

Boring sponges are bioeroders capable of tunneling through carbonate substrates by chemical dissolution and chipping. They have adversely affected oyster aquaculture and subtidal reef restoration along the east coast by fouling oyster clutch, eroding reef structures, and killing oysters. Previous studies describing the life history of boring sponges suggest a strong influence of temperature on sponge growth and reproduction. However, responses of growth and gamete production to temperature differ between temperate and tropical systems, suggesting possible location and species-specific variations. No work has been done yet to examine the species, life histories, and distribution of boring sponges in Mosquito Lagoon, a subtropical estuarine system and location of many successful oyster restoration projects. Recently, due to sea level rise and storm-associated high water events, both restored and natural reefs in Mosquito Lagoon have been submerged for longer time periods and are now showing signs of boring sponge infection. Once infected, shell clusters break off and wash up on reefs (64% of loose clusters on reefs restored before 2010 were infected; 13% on newer restored reefs; 46% on natural reefs). Surveys show that boring sponge primarily occurs on the deeper seaward edges of reefs, and loose clusters with signs of boring sponge activity tend to be larger and incorporate more live oysters than uninfected clusters. This work aims to assess the expected synergistic impact of boring sponge and boat wakes on intertidal oyster reef restoration by determining the breaking strength of infected oyster shell. Coupled with life history studies, this work will inform oyster restoration improvements aimed at prolonging reef lifespan and serve as a model for reef restoration in subtropical areas affected by boring sponge.

60.2 FARINA, SC; Harvard University; *stacy.farina@gmail.com*
Virtual fish gills: Computational modeling to examine hydrodynamic trade-offs in gill microstructures
When compared with air, water is a poor respiratory fluid, with a high viscosity and low dissolved oxygen concentration. Therefore, fluid dynamics likely play a large role in natural selection of respiratory morphology of vertebrates that rely on aquatic respiration, shaping the considerable diversity in the microstructures of fish gill tissues. Fish gills consist of long filaments (primary lamellae), which are covered with small folds of tissue (secondary lamellae) that are the main site of gas exchange. These secondary lamellae vary in shape, size, and spacing among species. In this study, I quantify fluid flow through secondary lamellae morphology in benthic species (including sculpins, snailfishes, and goosefish) and pelagic species (tunas, mackerels, and opah). Using a 3D computational model of the secondary lamellae that I have developed in COMSOL Multiphysics, I model the fluid dynamics of the gills of each species based on measurements from scanning electron microscopy. By measuring flow rate through and around the secondary lamellae over a range of pressures, I have identified a hydrodynamic trade-off between percent efficiency and absolute effectiveness of individual lamellae. While pelagic species are optimized for lamellae efficiency, the lamellae of benthic species may be more effective at the same differential pressures. [Supported by NSF BIO PRFB 1523836]

P2.210 FARLEY, GM*; ADLER-IVANBROOK, BSR; MERZ, RA; Swarthmore College; *gfarley1@swarthmore.edu*
Two photosynthetic symbionts differentially control light response behavior in a clonal anemone (Anthopleura elegantissima)
The clonal anemone *A. elegantissima* has facultative mutualisms with two photosynthetic symbionts. Anemones predominantly hosting the unicellular green alga *Elliptochloris marina* are more light sensitive and are found in lower intertidal or shaded regions compared to brown anemones inhabited by the dinoflagellate *Symbiodinium*. *A. elegantissima* attach debris to their body, presumably protecting their tissues from excess light exposure. Little is known about how anemones perform this decorating behavior, nor its relationship to symbiont type. Using time-lapse video we established that particles are attached in a matter of seconds when verrucae make contact with them through expansion and contractions of the body wall. Tentacles are usually not used to position particles. Attachment strength of pebbles initially increases with time (1.1-7.3g at 6h, 1.5-24.8g after 48h). We hypothesized that anemones with light sensitive *E. marina* decorate more when exposed to light than those with *Symbiodinium*. To test this, anemones in both light and dark treatments were allowed to attach pebbles for 24h. Green and white (asymbiotic) anemones increased decorating in the light compared to the dark, consistent with the idea that this behavior protects them from sunlight. Brown anemones attached the largest number of pebbles over all, and did not differ between treatments. When allowed to travel freely along a light-dark gradient, white and green anemones preferred shaded areas, while brown anemones had no preference. Pebble cover on white anemones increased their preference for light areas of the tank. These findings suggest a differential control of decorating behavior based on symbiont type, and further verifies that this behavior is related to light exposure.

64.1 FARMER, C/G; University of Utah; *cg.frmr@gmail.com*
PULMONARY AERODYNAMIC VALVES: FORM, FUNCTION, EVOLUTION
Aerodynamic valves in the lungs of birds cause unidirectional flow of gases through a circuit in the paleopulmo, a circuit that consists of dorsobronchi, parabronchi, and ventrobronchi (dpv). These fluid valves have fascinated biologists for many years, but remain incompletely understood. On inspiration, why doesn't air flow directly through the ventrobronchi into the cranial set of air sacs as they expand, rather than bypassing these airways to flow through the d-p-v circuit before entering the cranial air sacs? Furthermore, during exhalation, why do the gases in the caudal air sacs travel through the d-p-v system, rather than passing directly out of the body by way of the intrapulmonary bronchus? A guiding dam, located in the caudal region of the dpv circuit, was proposed by Hazelhoff as a mechanism that could create unidirectional flow, and physical glass models proved that such a dam is capable of converting tidal flow into unidirectional flow. In this model, the topography of the cranial region of the d-p-v circuit is not a critical component of the valves. However, experiments debilitating parts of the respiratory system, through either cannulations or by filling these parts with physical plugs indicate that the topography of in the cranial region of the lung is indeed critical to proper valve function. The discovery of unidirectional flow in crocodilians and lizards has enabled a comparative approach to be used to help throw into sharp relief features of this complex anatomy that are evolutionary conserved, and therefore possibly important to proper valve function, from features that are highly derived and may therefore play no, or a minimum, role. This comparative approach corroborates the importance of the cranial aspect of the topography to the aerodynamic valves, and may explain why this region of the lung is generally more cartilaginous, preserving the shape of the airways to ensure the valves function properly.

86.6 FARRELL, KP*; WANG, Q; ELSON, D; NINKOVIC, I; MARVI, H; Arizona State University; *kpfarre1@asu.edu*
Bio-Inspired Switchable Adhesives for Space Applications
In space robotics, one of the main concerns is to minimize the energetic cost of the system. This concern may be addressed by the implementation of gecko-inspired switchable adhesives into such robotic systems. By utilizing a passive attachment mechanism, a switchable adhesive will minimize energy costs by only requiring energy during detachment. These adhesives will be fabricated with micro-scale fibrillar structures, inspired by the gecko foot. Geckos' adept ability to controllably conquer various terrains has been extensively studied in the past decade. However, the effects of extreme temperatures on the adhesives has not been much explored. For this study, switchable adhesives will be fabricated with PDMS that is highly robust in extreme temperatures and pressures. The adhesives will be characterized in an environmentally controlled chamber that can simulate the environmental conditions experienced at the International Space Station (ISS)—a high vacuum (10^{-4} Pa) and a range of temperatures from -160 °C to 120 °C. The preload, contact time, approach and retract velocities can be precisely controlled with the force characterization setup. A six-axis load cell will measure the forces with 1 mN resolution and the fibers will also be monitored with an inverted microscope attached to a high-speed camera. The goal of this study is to provide an effective and controllable attachment mechanism that will improve locomotion and manipulation control in robots that perform missions on the external surfaces of the ISS.

P3.30 FARTHING, SJ*; MONTALVO, AM; JORGENSEN, DD; Roanoke College; *Sjfarthing@mail.roanoke.edu*

Real-time Visualization of Hemocyte Aggregation in Response to Acute Bacterial Exposure in American Lobster Hemolymph

When foreign materials, such as bacteria, enter the hemocoel of the American lobster, a rapid immune response is initiated. Following acute bacterial exposure, most bacterial cells are cleared from the circulating hemolymph within 30 min, concurrent with a precipitous drop in the number of circulating hemocytes. Previous studies suggest that, in the presence of foreign material, hemocytes produce adhesion proteins that allow them to bind to the foreign material, as well as to other hemocytes, forming tight clusters referred to as nodules, which could explain their disappearance from the circulating hemolymph. In our experiments, fluorescence microscopy was used to observe, *in vitro*, hemocyte aggregation in lobster hemolymph in response to acute bacterial exposure. We used *Vibrio campbellii*, bioengineered to express green fluorescent protein (GFP), which allowed us to better-visualize the interaction between hemocytes and bacterial cells. Hemocyte responses were viewed in real-time using time-lapse videography. Images were taken at five second intervals over ten minutes and showed that hemocyte aggregates began to form within one minute following the introduction of *V.campbellii* into a hemolymph sample. Bacterial cells were seen to be enclosed in hemocyte aggregates within minutes after initial exposure to *Vibrio*. Our experiments suggest an apparent relationship between hemocyte response to bacteria and the hemolymph clotting mechanism.

P2.214 FASSBINDER-ORTH, C*; TRAN, T; Creighton University; *carolfassbinder-orth@creighton.edu*

Dicistrovirus infections in honey bees (Apis mellifera): establishment of an infection model

Honey bees (*Apis mellifera*) provide an abundance of pollination services to both agricultural crops and wild plants. However, over the past several decades honey bee populations have been declining due to human land use changes, ectoparasites and fungal, bacterial and viral diseases. The ectoparasitic mite, *Varroa destructor*, has been a large contributor to honey bee decline, as it is known to transmit many viruses that ultimately contribute to colony loss. Although several viral pathogens have been identified as leading factors in colony loss, the etiology of these infections is largely unknown due to the lack of honey bee virus stocks and controlled viral infection studies. We investigated the use of cricket paralysis virus (CrPV) as part of a viral infection model in honey bees. CrPV is a dicistrovirus known to infect honey bees that is closely related to other virulent honey bee viruses. For the study, adult honey bee workers were divided into the following groups: No injection control, Vehicle injection control, CrPV, *V. destructor* protein extract, or *V. destructor* protein extract + CrPV. Bees were placed in screened, miniature wooden hives and monitored every 24 hrs for 5 days. Dead bees were collected and viral load was determined. CrPV was isolated from dead bees and patterns of viral infection in all CrPV groups was determined. This model system will improve our ability to study honey bee responses to viral infections, and increase our understanding of the involvement of *V. destructor* in honey bee viral infections.

P3.159 FAYE, LE*; STILLMAN, JH; Romberg Tiburon Center for Environmental Studies, San Francisco State University , 1. Romberg Tiburon Center for Environmental Studies, San Francisco State University 2. University of California, Berkeley; *lfaye@mail.sfsu.edu*

Salinity and temperature stressors increase metabolic and grazing rates in Phyllaplysia taylori

Phyllaplysia taylori, a sea hare found in eelgrass beds along the Pacific coast, is an integral part of eelgrass ecosystems, consuming light-obstructing epiphytic growth from leaf blades. Estuarine eelgrass beds are ecologically important habitats that provide ecosystem services including carbon sequestration and sediment stabilization. Current efforts to re-establish these beds in the San Francisco Estuary make it necessary to understand which parts of the bay can host healthy *P. taylori* populations. This is especially important considering future climatic scenarios, which will amplify the natural daily and annual fluctuations of temperature and salinity that already occur throughout the bay. *P. taylori* individuals exposed for two weeks to predicted future high temperature and salinity scenarios were hypothesized to have significantly higher respiration and epiphyte grazing rates than individuals exposed to current scenarios, indicating the metabolic costs of temperature and salinity stress. High mortality rates were observed at the lowest salinity of 24ppt, and average grazing rates were 73% higher in individuals exposed to 27ppt than individuals exposed to 33ppt, indicating higher levels of stress and increased energy requirements at low salinities, and establishing a low salinity threshold. Continued experiments will use an orthogonal design to determine the effects of combined temperature and salinity stress. This study will help inform eelgrass restoration throughout San Francisco Bay by indicating the impacts of increased temperature and salinity fluctuations on the relationship between *P. taylori* and eelgrass bed health.

P2.167 FAZAL-UR-REHMAN, F*; MIRE, P; University of Louisiana at Lafayette; *fxf8444@louisiana.edu*

Investigating Mechanisms of Ototoxic Effects on Hair Cells using a Model Sea Anemone

Ototoxicity is the harm induced on the cochlear or vestibular system of the ear that may lead to hearing loss and tinnitus. There is no current treatment for ototoxicity, yet there are over two hundred medications that result in hearing loss. The mode of action of these drugs is not clearly understood. This research seeks to determine the pathway used by the antibiotic, Gentamicin, to induce hearing loss. The model organism used is *Nematostella vectensis*, a sea anemone which possesses hair cells used in prey detection that are remarkably similar to the hair cells of human ears. Similarities include apical hair bundle mechanoreceptors composed of actin-based stereocilia and cadherin-based tip-links, and a loss of mechanotransduction with exposure to aminoglycoside antibiotics. To test the effects of Gentamicin on anemone hair cells, anemones were exposed to 1 mM Gentamicin dissolved in 12 ppt seawater for 4 hours then tentacles were excised and processed for microscopy. Phase-contrast and fluorescence microscopy were used to measure morphological features of the hair bundles, to obtain density of bundles and to obtain density of nuclei on the tentacles. Results show a significant decrease in the density of the Gentamicin-treated hair bundles compared to seawater controls, yet no significant change in the morphology of remaining hair bundles, or in the number of nuclei. Thus, Gentamicin has an acute effect leading to hair bundle loss but does not lead to immediate hair cell death. Ongoing experiments are aimed at testing the effects of Furosemide, a loop diuretic linked to ototoxicity. Considering the many similarities between hair cells in anemones and those in human inner ears, it is hoped that information gained in these experiments may indicate the mechanistic pathway of the drugs that lead to hearing loss.

118.3 FEILICH, KL; Harvard University; *kfeilich@fas.harvard.edu*
Rethinking Gait: A New Approach to Defining and Comparing Gaits in Fishes
Comparative studies of fish swimming have been limited by the lack of formal, quantitative definitions of fish gaits. Swimming gaits are fluid, and defined categorically by the fin or region of the body that is used as the main propulsor (e.g. carangiform, anguilliform , balistiform, labriform). This method of categorization is limited by lack of quantitative rigor, the inability to incorporate the contributions of multiple propulsors, and the inability to compare gaits across categories. I propose an alternative framework for the definition, comparison, and categorization of fish gaits based on the propulsive contribution of each structure (body, fin) being used as a propulsor relative to a locomotor output. This approach is modular with respect to the number of propulsors considered, flexible with respect to the definition of the propulsive inputs and the locomotor output of interest, and designed explicitly to handle combinations of propulsors. Using this approach, gait can be defined as a trajectory through propulsive space, and gait-transitions can be defined as discontinuities in the trajectory through propulsive space. By measuring and defining gait in this way, patterns of clustering corresponding to existing categorical definitions of gait may emerge, and gaits can be rigorously compared across categories.

P2.270 FELIZARDO, C; HESSE, C; NEVILLE, N; PETTIGREW-EDGREN, M; REMLEY, M; VELEZ, K; MCCORMICK, SD; MONETTE, MY*; Western Connecticut State University, USGS Conte Anadromous Fish Research Center; *monettem@wcsu.edu*
Phosphorylation of the Na-K-Cl Cotransporter in the Gills of Atlantic Salmon in Response to Pharmacological Stimulation and Seawater Challenge
Atlantic salmon (*Salmo salar*) face the challenge of transition from freshwater to seawater during downstream migration. Prior to migration, salmon undergo the parr-smolt transformation during which they acquire seawater tolerance due largely to an upregulation of gill ion transport proteins. Much is known about transcriptional changes in the gill, however few studies have examined post-translational mechanisms involved in the regulatory response to seawater challenge in salmon. We examined activation of the Na-K-Cl cotransporter (NKCC) in the gills of Atlantic salmon in response to pharmacological stimulation *in vitro*, and to seawater challenge *in vivo*. Exposure of gill tissue to 25 µM forskolin resulted in rapid phosphorylation of NKCC as detected by SDS-PAGE followed by Western immunoblotting using an anti-phospho NKCC antibody. In a separate study, Atlantic salmon smolts acclimated to brackish water, were transferred to seawater and sampled after 0, 1, 4, 8, 24, and 72 hours. Plasma osmolality and chloride levels were elevated relative to controls 1 hour post-transfer to seawater, peaked at 8 hours, and subsequently exhibited a decline towards control levels. Despite high levels of gill NKCC protein, we did not detect a change in NKCC phosphorylation in response to acute seawater challenge. Our results suggest that rapid activation of pre-existing NKCC in the gill is not part of the regulatory response to acute seawater challenge in this species.

35.4 FELLER, KD*; GONZALEZ-BELLIDO, PT; University of Cambridge; *kate.feller@gmail.com*
To Strike, or Not to Strike? - Sensorimortor Control of the Mantis Shrimp Weapon Deployment
Controlling how the body is propelled through space is paramount for the survival of most animals. Many species, including humans, use feedback provided by their visual and proprioceptive systems to correct or confirm body movements. Though, for many high performance behaviors, such as catching a fast incoming ball, the appropriate movement must be anticipated from a short observation period and actuated without sensory feedback. Understanding how visual information is processed and re-coded in a predictive manner for the purpose of fast movement implementation is a fundamental question in neuroscience. Most investigations into the neural basis of ballistic movements in predatory species focus on early circuits, with less focus place on the sensorimotor conversion for this type of behaviour. Here I present results from a new investigation into the sensorimotor control of the fastest predatory strike on earth, boasted by stomatopod, or mantis shrimp crustaceans. Since reloading the strike weaponry takes time and energy, if a stomatopod misses their target they may decrease their fitness by not getting to eat or failing to defend themself from an assailant. Localization of the strike upon a target is thus essential to stomatopod survival and reproductive success. First, we used high-speed video to characterize the strike behaviour of the spot-tail mantis shrimp (*Squilla mantis*) in the laboratory. We then used histological and extracellular recording methods to identify groups of descending neurons responsible for releasing the stomatopod strike. This work examines the neural controls for releasing the stomatopod's ballistic strike system as well as the visual parameters that influence the strike decision-making process (to strike or not to strike?).

105.4 FELLOUS, A*; LABED-VEYDERT, T; LESCAT, L; VOISIN, A.S; LOCREL, M; EARLEY, R.L; SILVESTRE, F; Laboratory of Evolutionary and Adaptive Physiology, University of Namur, Rue de Bruxelles 61, 5000 Namur, Belgium., Department of Biological Sciences, University of Alabama, 300 Hackberry Lane, Box 870344, Tuscaloosa, AL 35487, USA. ; *alexandre.fellous@unamur.be*
DNA methylation reprogramming during development in the self-fertilizing mangrove rivulus, Kryptolebias marmoratus, and its environmental sensitivity.
Kryptolebias marmoratus is native from the mangrove of the Gulf of Mexico. It presents great adaptive capacities and is characterized by a high level of phenotypic plasticity. In natural populations, hermaphrodites coexist with a low proportion of males (androdioecy) and it displays the unique ability for a vertebrate of self-fertilization. As a new biological model, mechanisms controlling the key transitions during its life history remain largely unknown. Among them, DNA methylation has important regulatory functions controlling gene expression, and thus the phenotype. Here, we explored the dynamic of global DNA methylation by LUMA assays. Significant differences between hermaphrodite ovotestes and male testes were observed (87.2% and 79.6%, respectively). After fertilization, a decrease in DNA methylation occurred from 27.8% in fertilized eggs to 15.8% in gastrula, immediately followed by an increase and re-establishment of the adult pattern by the stage 26 (liver formation) (70.0%). In addition, characterization of genes coding for DNA-methyltransferase enzymes (DNMT1, DNMT3A and DNMT3B) suggests evolutionary conservation of this family. Together these results provide evidence of an original reprogramming pattern of DNA methylation which, was investigated by temperature exposures. Altogether, we hypothesize that DNA methylation may have a crucial role in adaptive evolution of the rivulus.

P1.43 FERGUSON, SM*; SCHOECH, SJ; University of Memphis; *s.ferguson@memphis.edu*

Now you're speaking my language! Florida scrub-jays (Aphelocoma coerulescens) are more aggressive toward local variants of a geographically variable, female-specific call

Among populations, songs or calls may represent evolutionary isolating mechanisms due to localized variation and preferences for familiar patterns or structure. Research on geographic variation has typically focused on male song, which tends to be more prominent and variable than female vocalizations in temperate species. Florida scrub-jays (*Aphelocoma coerulescens*, FSJ) are cooperatively breeding, non-migratory corvids that defend single-pair territories. Territorial females use a sex-specific 'rattle' call that has been characterized as being from one of three main regional dialects: the rapid rattle, the hiccup rattle, and the soft rattle. We hypothesized that FSJs differentiate between rattle call dialects, with the prediction that local dialects would elicit the most aggressive responses. We recorded rattle calls at Archbold Biological Station (Venus, FL; hiccup), Oscar Scherer State Park (Osprey, FL; hiccup), and Seminole State Forest (Eustis, FL; rapid) and conducted playback trials at ABS and SSF. At SSF, FSJs responded more aggressively to the local rattle type than either foreign rattle ($p < 0.001$). At ABS, FSJs responded most aggressively to the local hiccup rattle ($p < 0.001$), and showed a nonsignificant trend to respond more aggressively to the nonlocal, same-dialect rattle from OSSP than the foreign dialect ($p = 0.056$). Thus, in FSJs, local female dialects elicit stronger behavioral responses than foreign dialects, mirroring a common pattern seen in geographically variable male songs of other species. Analyses of population-level genetics in FSJs suggest the existence of several distinct genetic groups that roughly align with the distribution of rattle call dialects. Taken together, these results suggest an important role for female call variation on the population-level genetic structure of the species.

20.3 FERGUSON, SM*; SCHOECH, SJ; University of Memphis; *s.ferguson@memphis.edu*

Conspecific call playback leads to an exaggerated adrenocortical response to handling stress in Florida scrub-jay (Aphelocoma coerulescens) nestlings

Though altricial young are typically isolated in nests or burrows during development, they may be influenced by their surrounding environment. For instance, acoustic signals between conspecifics, including parents, may be received by developing young, and nestlings may respond behaviorally to calls from predators, conspecifics, and parents; however, little is known about physiological responses to such signals. We hypothesized that Florida scrub-jay (*Aphelocoma coerulescens*) nestlings would alter steroid levels in response to conspecific call playback and parental defense. We conducted conspecific, heterospecific, or no call playback at nests, recorded parental and nestling behavioral responses, and measured corticosterone (CORT) and testosterone (T) in nestlings. Adults responded aggressively to conspecific call playback, but nestling behavior did not differ from controls (begs, begging time, and feedings, $p > 0.3$). Nestling T ($p > 0.3$) and CORT ($p > 0.3$) did not differ from controls immediately following playback, but following the stress of a 10 min restraint, nestlings exposed to conspecific call playback had higher stress-induced CORT levels than nestlings exposed to no playback ($p = 0.001$). These results suggest that, while not directly influencing baseline CORT in nestlings, conspecific vocal cues may nevertheless prime the HPA axis for a heightened response to subsequent stress. As developmental CORT exposure can affect growth rates and body size of nestlings, as well as have long-term effects on HPA axis responsiveness and behavioral phenotype, these results may have implications for high-density populations in which aggressive encounters are common or species for which vocal communication is prominent.

74.7 FERGUSON, LV*; DHAKAL, P; BUCKING, C; SINCLAIR, BJ; University of Western Ontario, York University; *lfergus9@uwo.ca*

Cold "colon"-ization: seasonal changes in the gut microbiome of the spring field cricket, Gryllus veletis

During overwintering, ectotherms experience and respond to a range of environmental pressures; however, we know little of how biotic interactions influence overwintering success. Notably, the impact of the microbiome on host physiology is likely influenced by how overwintering stressors, such as low temperatures, change its composition and function. To understand the role of the microbiome in determining the success of overwintering insects, we began by exploring how overwintering affects the composition of the gut microbiome of the spring field cricket, *Gryllus veletis*. We exposed *G. veletis* to a simulated change in seasons that mimicked temperatures and photoperiods in London, Ontario, Canada, and identified the composition of the community of gut bacteria at time points corresponding to summer, autumn, early winter, mid-winter, late winter, and spring. We found that the composition of the gut microbiome is similar in summer and autumn and is dominated by the classes Bacteroidia and Clostridia. In winter, the composition shifts to favour Bacteroidia, suggesting that bacteria in the class Clostridia do not perform as well at low temperatures. In spring, the composition shifts once again as Gammaproteobacteria flourish. These changes in composition across season suggest that overwintering can markedly shift the microbiome into the growing season. These changes may influence how hosts respond to the multiple stressors associated with winter - from the response to cold stress to immune challenges - and it will next be important to determine how these shifts influence host success.

P2.199 FERGUSSON, R*; CLANCY, D; DONAHOE, K; COHEN, SC; San Francisco State University - Romberg Tiburon Center, Tufts University; *ryan.fergusson.270@gmail.com*

Characterizing the Biodiversity of Botryllids

Botryllids are colonial styelid ascidians renowned for their advanced allorecognition and regenerative capabilities. These traits show intriguing patterns across clades and species. However, much of what is understood about their reproductive behavior and distribution in benthic and fouling communities is based on what is known from invasive botryllids. Here, we take advantage of a substantial natural assemblage of ascidians from the Verde Island Passage of the Philippines, named the center of the center of marine biodiversity in the Coral Triangle. We found high botryllid diversity in a relatively small area (1100 km2) , when compared to lower diversity in much larger global sampling efforts to date. Our data shows 11 novel mitochondrial cytochrome oxidase 1 haplotypes in just 14 samples, with the remarkable discovery of 4 new clades in this small number of samples. Further, of the currently characterized globally invasive species of botryllids, none have yet to be detected in this highly biodiverse ecosystem. This project is a first step towards characterizing botryllid diversity and leading towards linking molecular data with historic species descriptions based on morphological features.

S3.10 FERKIN, M.H.; University of Memphis; *mhferkin@memphis.edu*

The Effects of Food Availabilty on the Maternal and Sociosexual Behaviors of Meadow Voles

Many female small mammals, such as meadow voles, *Microtus pennsylvanicus* , may face limited food availability during behavioral estrus, pregnancy, postpartum estrus and lactation. The amount of food that is available to these females may influence their behavior and reproductive success. We examined the effects of nutritional stress on aspects of the behavior of female meadow voles in different reproductive states, including behavioral estrus, pregnancy, postpartum estrus and lactation. In doing so, we also examined if nutritional stress faced by dams affected the phenotype of their offspring. We found that 6 hours of food deprivation (FD) was sufficient to decrease the sexual behaviors of female voles in behavioral estrus relative to female voles that did not face FD. Next, we discovered female voles that were food deprived (FD) or food restricted (FR) during late pregnancy became sexually less receptive and produced scent marks that were no longer as attractive to male voles on the first day of lactation (the onset of postpartum estrus) compared to that of pregnant female voles that were not FD or FR during late gestation. FD and FR pregnant female voles did not enter postpartum estrus (PPE), whereas, control females did enter PPE. We also found that FR during lactation caused dams to spend less time engaged in maternal behavior compared to control dams. Dams that were FR during days 8-14 of lactation displayed the most pronounced decline in maternal behavior relative to dams that were FR during days 1-7 or days 15-21 of lactation. In addition, FR 8-14 dams reared offspring that had lower body mass at weaning and at sexual maturity and had deficits in sexual behavior as adults. Thus, FD and FR can affect the phenotype of adult female voles and induce similar deficits in their offspring. These persistent effects may affect the fitness of individuals within a population and the demography of that population.

3.3 FERNER, MC*; HODIN, J; NG, G; LOWE, CJ; GAYLORD, B; SFSU and Romburg Tiburon Center, CA, USA, Friday Harbor Labs, U. of Washington, USA, Bodega Marine Lab, UC Davis, CA, USA, Hopkins Marine Station of Stanford U., CA, USA, Bodega Marine Lab, UC Davis, CA, USA; *larvador@uw.edu*

Tumbling Pass: Sand Dollar Larvae Show Genetic Variation for Their Turbulence Responses at Settlement

Sea shore animals and non-animals are often characterized by complex life cycles involving a planktonic dispersal period followed by settlement and metamorphosis back into shoreline benthic habitat. Underlying this common strategy in animals are substantial differences, even in closely related species, in the cues that their dispersing larvae use to positively identify suitable nearshore habitat for their generally irreversible transformation. The vast majority of studies on such 'settlement cues' to date have focused on olfactory stimuli to which larvae respond - including compounds produced by algae, conspecifics or bacterial biofilms. Here we report on intraspecific variation for larval responses to an entirely different class of settlement stimulus: nearshore turbulence. We have previously shown that larvae of sea urchins and sand dollars (including the Pacific sand dollar, *Dendraster excentricus*) show hastened onset of settlement following exposure to turbulence of an intensity characteristic of wave impacted shores. Here we show that larval offspring of certain *D. excentricus* parents (either male or female) show consistently enhanced responses to turbulence when compared to larvae deriving from different parents. In other words, there is within population genetic variation for the turbulence responses in this species. We will consider this finding both in terms of the possible advantages of bet hedging with respect to settlement decisions as well as variation in turbulence responses as a plausible mechanism of speciation.

S1.1 FERRARI, Maud C.O.; University of Saskatchewan, Canada; *maud.ferrari@usask.ca*

Behavioural and cognitive ecology of predation risk assessment in a changing world

Almost all organisms on Earth live in environments that have been altered, often drastically, by humans, via habitat destruction, the spread of exotic species, pollution or climate change. In the context of predation, such environmental change can disrupt a number of steps in the predation sequence, leading to change in the natural balance of interactions between predators and prey. In my talk, I will highlight the ways in which such alterations can modify the sensory and behavioural ecology of risk assessment by aquatic prey, and by extension, profoundly modify the outcome of predator-prey interactions.

5.5 FERRIS, KG*; PHIFER-RIXEY , M; CHAVEZ, AS; BI, K; BALLINGER, M; HEYER, GP; SUZUKI, TA; NACHMAN, MW; UC Davis, UC Berkeley, UC Berkeley; *kgferris@gmail.com*

The genomics of rapid adaptation to climatic extremes in house mice across the Americas

The house mouse, Mus musculus domesticus, colonized the Americas in conjunction with early European settlers 200-400 years ago. Since their arrival, house mice have rapidly expanded their range and now occur in a variety of novel and extreme habitats from Alaska to Tierra del Fuego making them an excellent system for identifying loci that underlie rapid environmental adaptation. We have collected tissue, phenotypic data, and live mice from latitudinal transects across North and South America that vary dramatically in temperature, precipitation, and seasonality. We find phenotypic clines in several adaptive traits including body size and coat color. In order to examine genetically based phenotypic differences in behavioral and physiological differences involved in environmental adaptation, we collected live mice from populations at the extremes of these transects and bred them in a common laboratory environment for five generations. Among other interesting differences, we find that cold adapted mice from New York & Canada build bigger nests and are more active than Tucson, Florida, & Brazil mice. To identify the genetic basis of environmental adaptation in house mice we use both population genomic and quantitative trait locus (QTL) mapping approaches. We find that exciting candidate genes involved in processes such as osmoregulation, energy metabolism, and circadian rhythms are under selection. Therefore we conclude that despite their recent introduction to the Americas, house mice have undergone rapid genetic diversification and adaptation to novel climates.

5.4 FETTERS, TL*; MCGLOTHLIN, JW; Virginia Tech, Blacksburg, Virginia Tech, Blacksburg ; *tamarafetters@gmail.com*
Geographic Variation in Incubation Duration and Egg Laying Patterns in an Invasive Lizard (Anolis sagrei)
During biological invasions, non-native invaders often experience environments that differ substantially from those found in their native range; these novel conditions can impose strong directional selection and lead to rapid phenotypic divergence between native and invasive populations. The brown anole (*Anolis sagrei*) is a small lizard native to Cuba and the Bahamas that has invaded the southeastern United States over the past century. Native and invasive populations experience different climatic variables with more northern invasive populations experiencing lower mean annual temperatures and shorter breeding season lengths than more southern native populations. Because invasion success hinges on the ability of a population to survive and expand, we hypothesized that invasive populations whose reproduction is limited by a shorter breeding season would experience strong selective pressure to decrease egg incubation time and the spacing between egg lays. We collected brown anoles from 4 native island populations in the Bahamas and from 4 populations in the southeastern United States ranging from southern Florida to Georgia. Eggs produced by females from each population were incubated at 28°. We found that eggs from invasive populations hatched significantly faster than those from native populations, and that females from invasive populations had shorter intervals between egg lays than did females from native populations. Together, these results support that the shortened breeding season experienced in the invasive range has led to the rapid divergence of life history traits in *Anolis sagrei*.

S1.6 FEY, SB; Yale University; *Samuel.fey@gmail.com*
Species interactions in variable environments: How temporal patterns of temperature can influence competitive interactions
While climate warming occurs over a background of variation due to cyclical processes and irregular events, the temporal structure of the thermal environment is largely ignored when forecasting the dynamics of interacting species. Ecological theory predicts that high levels of temporal autocorrelation in the environment- relatedness between conditions occurring in close temporal proximity- will favor populations that would otherwise have an average negative growth rate by increasing the duration of favorable environmental periods. Here, I invoke such theory to explain the success of biological invasions and evaluate the hypothesis that sustained periods of high environmental temperature can act synergistically with increases in mean temperature to favor the establishment of non-native species. I present data from a recent field mesocosm experiment that measures the population dynamics of the non-native cladoceran zooplankter *Daphnia lumholtzi* and a native congener *Daphnia pulex* in ambient temperature environments (control), warmed with recurrent periods of high environmental temperatures (uncorrelated-warmed), or warmed with sustained periods of high environmental temperatures (autocorrelated-warmed), such that both warmed treatments exhibited the same mean temperature but exhibited different temporal structures of their thermal environments. I interpret the results of this experiment in the context of simple mathematical models to show how alterations in performance can occur alongside increasing temporal autocorrelation, even among environments with the same mean temperature.

22.4 FIELD, K.E.*; JOHNSON, K.K.; MARUSKA, K.P.; Louisiana State University; *kfield3@lsu.edu*
How do sexually-relevant olfactory and visual signals affect behavior and neural activation in the social African cichlid, Astatotilapia burtoni?
Across vertebrates females are often senders of potent chemical signals that provide information important for coordinating reproductive events. In several fish species, these chemical signals can induce robust reproductive behavioral responses in male receivers. How the brain processes these sexually-relevant signals to elicit this behavior, however, remains poorly understood in fishes. Here, we used the highly social African cichlid, *Astatotilapia burtoni*, to investigate how sexually-relevant chemical and visual signals from gravid (reproductively-receptive) females influence behavior and brain activation patterns in dominant males. We presented chemical signals alone (control water or gravid female-conditioned water) and paired with matching visual signals (no fish control or gravid female) and found that *A. burtoni* males need sexually-relevant visual signals to engage in reproductive behaviors, and the number of reproductive behaviors increased when exposed to visual and chemical cues together. When female-conditioned water was delivered alone, males exhibited increased swimming and overall activity compared to when presented with control water. Using the immediate early gene *cfos* as a proxy for neural activation, we found that brain regions of the social decision making network show differential activation in fish exposed to chemical and visual cues together compared to chemical cues alone. These data provide insight on potential distinctions between brain regions and cell populations involved in olfactory processing itself from those involved in integrating different sensory modalities to elicit appropriate social behavior.

P1.151 FILIPPI, NN*; MORGENROTH, H; GMUCA, NV; KUHN, CE; DICKERSON, B; LIWANAG, HEM; Cal Poly SLO, Adelphi Univ. , NMML; *nfilippi@calpoly.edu*
Under Pressure: Instrumentation methods affect fur seal pelt function during simulated dives
The tracking of marine mammals with electronic devices enables researchers to gain a better understanding of their movements and at-sea behavior. In pinnipeds (seals and sea lions), electronic instruments are typically glued to the animal's fur, either directly to the pelage or on a neoprene patch. When instruments are recovered for data collection they are retrieved either by cutting the fur or by cutting through the neoprene patch and leaving a layer of neoprene attached to the animal. The impact of these modifications to the animal's pelage is presumed to be minimal, but this has not been explicitly investigated. This study examined the effects of instrument attachment and removal on the pelts of northern fur seals. Northern fur seals rely primarily on their fur for insulation in water and are thus ideal for determining the impacts of instrumentation on pelage function. To assess the extent to which water is able to penetrate the air layer of fur seal pelts during diving, we measured the volume of air released under hydrostatic pressure. Dives to 120m were simulated in a hyperbaric chamber for (a) unmodified pelts, (b) pelts with the top layer of fur cut, and (c) pelts with a layer of neoprene attached. We also measured the thermal conductivity of unmodified and modified pelts for both instrumentation methods. Cutting the fur during tag removal allowed water to penetrate the fur under pressure and reduced the thermal function of the pelt in water. In contrast, a neoprene patch better maintained the air layer and the insulation. This is the first study to measure the thermal consequences of instrumentation in fur seals and the results suggest that the use of neoprene in instrument attachment may minimize those consequences.

85.6 FINGER, JW*; HOFFMAN, AJ; WADA, H; Auburn University; *jwf0016@auburn.edu*

The Effect of Heat Shock on Constitutive and Inducible Heat Shock Proteins and Corticosterone in the Zebra Finch

Following stressor exposure, organisms mount physiological and behavioral responses aimed at survival to enable species perpetuation. Two major physiological responses include the glucocorticoid (GC) stress response and the heat shock response, mediated by heat shock proteins (HSPs). There have been some studies into GC and HSP interactions, which suggests the two may interact and possibly even mediate one another. However, how these responses interact is not clear in part because it is hard to compare studies that measure constitutive (always active; cHSPs) and/or inducible (stress-induced; iHSPs) HSPs at various times after stressor exposure. In some studies, samples may have been taken too rapidly to understand how stress-induced GC levels affect HSPs. As such, our aim in this study was to utilize a commonly used stressor (heat stress) to examine how stressors affect circulating levels of cHSPs, iHSPs, and GCs over time. In this study, 26 (13/treatment) female zebra finches (*Taeniopygia guttata*) were either heat stressed (38°C) or put in a control incubator at room temperature for 3 hours. They were then returned to cages and left alone until blood sampling 2, 4, 6, and 20 hours after treatment ended. Baseline blood samples were obtained a week before treatment. Plasma corticosterone, along with erythrocyte HSPs were measured. Constitutive HSP70 (i.e., HSC70) levels were significantly reduced after 2 and 4 hours, regardless of treatment ($p=0.0104$), suggesting an impact of handling stress on this reduction. However, no effect of Time or Treatment was observed on corticosterone (CORT) levels, suggesting the birds may be habituated to repeated sampling or that the temperature was not high enough to induce changes in CORT. Results are forthcoming regarding effects on inducible HSP70 and HSP90. Our study should provide a basis for further research into HSP and GC crosstalk.

P3.136 FINK, AA*; VEECH, JA; Texas State University, San Marcos; *afink@trinity.edu*

Analysis of dispersal, survival, and habitat selection of reintroduced Texas Horned Lizards (Phrynosoma cornutum).

The historical range of the Texas Horned Lizard (THL, *Phrynosoma cornutum*) spans across most of Texas, all of Oklahoma, parts of Kansas and New Mexico, and most of northern and central Mexico. However, the species has experienced range contraction and population declines throughout much of the range. There is no substantial evidence to indicate any one cause, so it is likely that the decline has been triggered by multiple factors. Possible threats include Red Imported Fire Ants (*Solenopsis invicta*), herbicides and pesticides, habitat destruction and disturbance, and collection. Further investigation is needed to fully understand the threats these iconic lizards face, and state natural resource agencies such as the Texas Parks and Wildlife Department are studying reintroduction techniques to reestablish extirpated populations. In addition, the habitat description given by many is vague, such as that from Burrow et al. (2001): "a mosaic of bare ground, herbaceous vegetation, and woody vegetation in close proximity." Research using radio transmitters to track individuals can provide more accurate data and thorough knowledge of habitat use. The purpose of this study is to investigate the factors influencing THL dispersal, survival, and habitat selection following reintroduction. As part of an ongoing project at Mason Mountain Wildlife Management Area, near Mason, Texas, a total of 1,351 points were collected from 22 reintroduced lizards using radiotelemetry from May to August 2016. Data was collected on habitat variables of these points and randomly located points. Harvester Ant (*Pogonomyrmex* or *Ephebomyrmex*) locations were recorded within the study area. Future analysis of the data will provide insight on proper techniques to successfully reestablish extirpated populations of THL across Texas.

31.3 FINKLER, M.S.; FINKLER, Michae; Indiana Univ. Kokomo; *mfinkler@iuk.edu*

Effects of varying temperature during early development on hatching size in Chelydra serpentina.

Turtle embryos may experience different thermal conditions during different stages of incubation, but laboratory studies frequently incubate eggs under single constant temperatures for the entirety of development. When incubated under single constant temperatures, increased temperature leads to earlier hatching and smaller body sizes in snapping turtle *(Chelydra serpentina)* neonates. In this study, I incubated snapping turtle eggs at three different temperatures (23, 25, and 27 °C) for the first 21 days of incubation, then transferred the eggs to a constant 25 °C for the remainder of development. Dry embryo mass at Day 21 was highest in the 27 °C group and lowest in the 23 °C group, and dry egg content mass at Day 21 was significantly higher for eggs incubated at 23 °C than those incubated at higher temperatures. Mean incubation durations for the 23, 25, and 27 °C early incubation temperatures were 78.1, 74.3 and 66.3 days respectively. Carcass masses and carapace lengths were larger, and yolk sacs were smaller, in hatchlings exposed to 27 °C early in development than those exposed to the two lower temperatures. My findings indicate that temperature variation during early embryonic development can have lasting effects on growth patterns during the remainder of development, with higher temperatures during early development promoting increased growth during this period.

P1.125 FIORETTI, SE*; FALVEY, EL; BAKER , DM; University of Mary Washington, Fredericksburg, VA, University of Mary Washington; *sfiorett@umw.edu*

Embryonic Development of the Stress Axis in Two Model Teleost Species

The zebrafish (*Danio rerio*) is a commonly studied model organism utilized for stress research due to functional similarities between the hypothalamus-pituitary-adrenal (HPA) axis and teleost hypothalamus-pituitary-interrenal (HPI) axis. The Japanese medaka (*Oryzias latipes*) is another promising model teleost for stress axis research; however, there has been considerably less research done on the embryonic development of key stress axis components in this species compared to zebrafish. To further the utility of both species as model organisms for stress research, we have characterized the development of the HPI axis in both by measuring expression levels of genes encoding key HPI hormones, receptors, and enzymes during embryonic development. Toward this goal, we isolated total RNA from zebrafish embryos collected at 12 time points, from 10 hours post-fertilization (hpf) to just prior to hatching at 48 hpf, and from medaka embryos collected at 9 time points, from 2 days post fertilization (2 dpf) to just prior to hatching at 8 dpf. We used quantitative PCR to determine the relative expression of the target HPI axis genes normalized to the housekeeping gene β-actin. We found that in the medaka, glucocorticoid receptor (GR) mRNA levels significantly increase from 2 days post fertilization (dpf) through 6dpf, then remain fairly steady until 8 dpf. Conversely, in the zebrafish, we found that GR mRNA levels remain relatively unchanged from 10 hours post fertilization (hpf) up to 48 hpf. These initial results indicate that there are critical differences in the early development of the HPI axis among teleost fishes.

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Effects of maternal corticosterone on the physiology, morphology and behaviour of nestling tree swallows

Environmental cues are translated into functional responses via glucocorticoid hormones (corticosterone or cortisol). Across taxa, maternal glucocorticoids have been hypothesized to act as a signal to offspring of local environmental conditions resulting in changes in offspring physiology and behaviour. However, results of studies of the prenatal transfer of glucocorticoids have been inconsistent. We manipulated adult female tree swallows pre-egg laying using subcutaneous silastic implants filled with corticosterone (the dominant glucocorticoid in birds) or empty implants (controls). Nestlings were monitored from hatching until fledging and various morphometric measurements were taken. To examine the interaction between maternal treatment and an ecologically-relevant stressor, we monitored nestling baseline and stress-induced corticosterone levels before and after food-deprivation. Nestling behavioural response to an isolation stress was also measured. The contribution of elevated maternal corticosterone to phenotypic variation in offspring will discussed in light of maternal matching.

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Convergent mechanisms of parental care: a poison frog perspective

The intense and often elaborate behaviors that encompass parental care are remarkable and require the coordination of hormonal, neural, and molecular changes, many of which remain poorly understood. The biological mechanisms promoting parental care are best characterized in mammals, but smaller, simpler brain and a diversity of parental care strategies in non-mammalian species may provide critical insights into the evolution of parental care. Maternal care has evolved multiple times in amphibians, including in some Malagasy Mantella and South American Dendobrates poison frogs. Although these lineages diverged over 150 million years ago, there are striking similarities in maternal behavior, where in some species females provision developing tadpoles with unfertilized trophic eggs. Moreover, both frog clades are toxic and trophic eggs laced with alkaloid toxins may serve to protect as well as nourish tadpoles. We take advantage of convergent evolution in two poison frog species to ask whether (1) the neural and physiological mechanisms mediating parental care are similar across independent transitions to provisioning behavior and whether (2) both species provide alkaloid toxins to tadpoles through trophic egg feeding. Our work sheds light on the neuroendocrine factors that promote maternal care in amphibians and allows us to determine if the remarkable convergence of maternal egg across lineages relies on similar underlying mechanisms that facilitate both provisioning and protection of offspring.

2.4 FISH, FE*; WILIAMS, TM; WEI, T; West Chester Univ., PA, Univ. of California, Santa Cruz, Univ. of Nebraska, Lincoln; *ffish@wcupa.edu*

Tail Stands in Dolphins: Experimental Measurement of Force Generation using Bubble DPIV

Estimation of force generated by swimming dolphins has long been debated. The problem has been that early indirect estimates of force production for dolphins resulted in low values that could not be validated. Bubble Digital Particle Image Velocimetry (DPIV) was used to measure the hydrodynamic force production for dolphins during free swimming and demonstrated high force production. To validate the Bubble PIV and reconcile force production measurements, two bottlenose dolphins (*Tursiops truncatus*) performing tail stands were measured with Bubble DPIV. Microbubbles were generated from a finely porous hose and compressed air source. Displacement of the bubbles in the wake of the dolphin was tracked with a high-speed video camera. Oscillations of the dolphin flukes generated strong vortices and a downward directed jet flow into the wake. Application of the Kutta-Joukowski Theorem on measured vortex circulations yielded force values up to 1183 N during a tail stand. Another video camera recorded the height of the body above the water surface. Based on position of the dolphin's center of mass, the mass-force of the dolphin above the water surface was calculated. For the dolphin to hold its position above the water surface, the mass-force approximately balanced the vertical hydrodynamic force generated by the flukes. The results of this study demonstrated the fluke motion can be interpreted as a flapping hydrofoil that can generate high levels of sustained force roughly equal to the dolphin's weight and validated high forces measured previously from Bubble PIV for thrust generated in free swimming.

P1.248 FISH, FE*; WILLIAMS, TM; West Chester Univ., PA, Univ. of California, Santa Cruz; *ffish@wcupa.edu*

Chordwise Flexibility of Bottlenose Dolphin Flukes during Static Exercise

The forces that dolphins can produce by oscillation of the tail flukes have been debated for 80 years. Hydrodynamic analyses of the force production by the flukes have modeled these propulsors as rigid structures. The flukes, however, are composed of flexible elements including collagen fibers, which are arranged in a complex organization. The arrangement of the collagen fibers provides the flukes with both rigidity and flexibility. We investigated the effect of chordwise bending within the flukes of bottlenose dolphins (*Tursiops truncatus*) and determined how swimming effort could affect shape change of the flukes. Two adult male dolphins were video recorded from a lateral view as they statically pushing against a load cell at three levels of effort (Low: 61-98 N; Medium: 107-210 N; High: 314-527 N). While oscillatory frequency increased with increasing effort, heave amplitude remained constant. To measure the flexibility of the flukes, a Flex Index was computed as the ratio of the length of the chordline to the length of the camberline, where a value of one indicated a straight or unbent fluke. The Flex Index decreased with increasing effort. Average values of Flex Index were greater at the transitions between up-stroke and down-stroke compared to mid-stroke, particularly as effort increased. The flukes are flexed throughout the stroke cycle, which can have implications in the generation of propulsive force and efficiency.

P3.126 FISHER, AC*; CARPENTER, EJ; KOMADA, T; STILLMAN, J; WILKERSON, F; San Francisco State University; *afisher1@mail.sfsu.edu*

Ocean Acidification Effects on Photosynthetic Symbionts in the Sea Anemone Anthopleura xanthogrammica

In a world facing climate change, it is vital that we understand how ecologically significant marine species will be impacted by increasing temperatures and decreasing seawater pH. One ecologically important species in California and Oregon is the giant green anemone (*Anthopleura xanthogrammica*), which has two photosynthetic algal symbionts that make these anemones important primary producers in the intertidal zone. This study is to investivating the effects of changes in temperature and pH on anemones and their symbionts over a natural gradient along the coast of California and Oregon. Algal cell counts, chlorophyll a measurements, mitotic index, and anemone oral disk diameter are being used to evaluate abundance of symbionts and health of both symbionts and anemones. This study is testing the hypothesis that symbiont amount and animal size will both increase under conditions of higher temperature and lower pH. Sampling for this project occurred in late May and early August 2016 including Fogarty Creek, OR (44.84°N), Cape Arago, OR (43.31°N), Cape Mendocino, CA (40.34°N), and Bodega Head State Marine Reserve, CA (38.32°N). Historical data from the OMEGAS group was used to characterize the sites. In May, Fogarty Creek is the warmest site, and temperature decreases from north to south; all sites are significantly different from each other ($p<0.05$). At the same time, the northern sites are more basic, while the southern sites are more acidic. In August, these trends are reversed. Analysis of May samples and processing of August samples is currently in progress. The results of this study will help inform environmental policies, since radical ecological shifts may occur if anemones are able to outcompete other ecologically important intertidal species.

69.6 FISHER, CR*; JOCKUSCH, EL; Univ. of Connecticut; *cera.fisher@uconn.edu*

Comparative transcriptomics support the wing gene cooption hypothesis for the origin of the novel treehopper helmet

Understanding the origins of new characters is crucial to explaining the diversity of life. In the insects, new body parts often arise as projections of the body wall that are then molded by natural selection, e.g. beetles' horns. A stunning example of novelty is found in the hemipteran family Membracidae (treehoppers), sap-sucking insects with enlarged, elaborate projections of the pronotum (dorsal body wall) termed helmets. Treehopper helmets have been sculpted by natural selection into an array of structures aiding predator defense via crypsis, mimicry, and aposematism. Members of their sister group, the leafhoppers (Cicadellidae), exhibit the plesiomorphic condition, a flat, shield-like pronotum. We tested three hypotheses for the developmental origin of the treehopper helmet using comparative transcriptomics in four tissues of nymphal *Entylia carinata* (a treehopper) and *Homalodisca vitripennis* (a leafhopper). Differential gene expression analysis indicates that in the leafhopper, the pronotum and mesonotum are most similar, as would be predicted of serial homologs. In treehoppers, however, gene expression in the developing pronotum/helmet is most similar to that of wings. Many transcripts upregulated in both wings and helmet of the treehopper are known for their roles in Drosophila wing development, including *nubbin*, *vestigial*, and *wingless*. This preliminary evidence supports a wing-cooption scenario for the origin of the treehopper helmet, wherein elements of the wing-patterning network are redeployed in the novel context of developing pronotal tissue. We are now evaluating the functional significance of these expression similarities with comparative RNAi in *E. carinata* and milkweed bugs (*Oncopeltus*).

79.8 FISSETTE, SD*; BUSSY, U; CHUNG-DAVIDSON, Y-W; LI, W; Michigan State University; *sdfissette@gmail.com*

Perceived Competition Leads to Increased Pheromone Signaling in Male Sea Lamprey, Petromyzon marinus

Males of many species produce signals that aggregate conspecifics and attract mates. Males can alter signals in response to competitors. Relative to other sensory modalities, little is known about how chemical signals affect competition. The chemical communication system in sea lamprey, *Petromyzon marinus*, is well understood and offers a model to study the influences of chemical signals on male-male competition. Male sea lamprey aggregate on spawning grounds where they build a nest and signal to females using sex pheromones. A major component, 3keto-petromyzonol sulfate (3kPZS), induces short and long distance upstream movement of sexually mature females. Here, we examined the male response to simulated competition using 3kPZS as a stimulus. Simulated competition led to an immediate increase in 3kPZS release rate within ten minutes followed by a reduction to baseline levels over the course of an hour. Exposure to 3kPZS also led to increased bile acid synthesis and transport in tissue and plasma samples. This increase could be due to up-regulation of specific enzymes responsible for bile acid production and transport. Based upon our results, we suggest that by increasing synthesis and release, males improve their chances of matching or possibly exceeding competitors' signals, allowing them to better compete for mates.

P1.236 FLAMMANG, BE*; BECKERT, M; ANDERSON, EJ; NADLER, JH; New Jersey Institute of Technology, Georgia Tech, Grove City College, Georgia Tech Research Institute; *flammang@njit.edu*

Morphology and mechanics of remora adhesion

Adhesion, and in particular long-term reversible adhesion, to a wet or submerged surface is challenging. In the natural world, few organisms can adhere to underwater substrates and those that do generally use glue-like mechanisms or attach only to stationary objects. Remora fishes have evolved a unique adaptive ability - an adhesive disc formed from dorsal fin elements - that allows them to attach reversibly to actively deforming bodies of varying roughness and compliance that move at high speed. The adhesive disc is a hierarchical structure, in which the lamellae, spinules, fleshy outer lip, and cranial vessels all contribute to the generation of suction and friction for initial attachment and long-term hold. We found that remora body shape adds hydrodynamic advantages to adhesion and resistance to drag as well. The wall effect created by the flat disc approaching a host organism generates a suction pressure that helps to pull the remora to its host. Upon contact, the fleshy outer lip generates a viscoelastic seal as the lamellae rotate to produce a subambient pressure beneath the disc. Individual lamellar chamber pressures may be equalized by the anterior cardinal sinus. Lamellar contact with the host engages spinule interaction with the host surface, thereby generating frictional forces that oppose shear. Our continued assessment of these mechanisms and the material properties of these structures is leading towards a bioinspired adhesive device that will be useful in ecology, medicine, and defense.

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The Fight for Light: Biotic determinants of Nereocystis luetkeana distribution

Bull kelp, *Nereocystis luetkeana* , is the dominant kelp forest species in the Salish Sea and plays an important role in the marine coastal ecosystem. The biogenic structure formed by *N. luetkeana* provides habitat for marine mammals, crustaceans, echinoderms, mollusks, and fish and increases the productivity of the ecosystem. Throughout its lifecycle *N. luetkeana* faces a variety of biotic stressors that impact its distribution and abundance. Key biotic stressors are competition, sori availability, and predation. The relative impacts of availability of sori and competition on the abundance of *N. luetkeana* were explored through a subtidal experiment. Data suggests that competition between macroalge for light is the limiting factor in settlement and growth. Once the macroalga survives settlement it still faces other stressors, such as predation. Feeding trials with two species of kelp crabs, *P. gracilis* and *P. producta*, tested feeding electivity on *N. luetkeana*. Results suggest a preference in both species for juvenile stipe in comparison to juvenile blade and sori over non reproductive blade. *P. producta* also elected to eat mature blade over mature stipe. Identification of challenges faced by *N. luetkeana* has the potential to allow for more informed preservation and restoration.

38.8 FLORES, DV*; JANZEN, FJ; Iowa State University; *dvflores@iastate.edu*

Epigenetic inheritance and predisposition to sex in temperature-dependent sex determination

Vertebrates with temperature-dependent sex determination (TSD), a sex determining mechanism which relies on incubation temperature to determine the sex of developing embryos, are especially threatened by the impending changes in climate. Previous studies have suggested modes of inheritance in this system that may provide opportunities for these species to adapt to climate change, however a complete molecular mechanism remains elusive. Epigenetic studies have the potential to unlock crucial information previously cryptic in traditional genetic studies. DNA methylation is well-known for its dynamic ability to silence genes, and evidence is accumulating for its role in determining sex in TSD systems. Using the painted turtle, *Chrysemys picta*, as a model for TSD, this study investigated the heritability of DNA methylation and its ability to predispose individuals to a particular sex by observing the methylome at different life stages of related individuals. Clutches collected in the field were incubated at a temperature to produce both sexes. The adrenal-kidney-gonad complex was harvested from a subset of early-stage embryos and gonads from the remaining hatchlings were collected to compare basal and hatching methylation. These were also compared to the methylome of their respective mother to determine inheritance. Epigenetic inheritance has the potential to mediate the effects of climate change on the population dynamics of species with TSD. This can be leveraged by global conservation efforts, as well as evolutionary and ecological studies, as climate change threatens to extinguish reptiles with TSD.

P2.147 FLOREY, C. L.*; MARTIN, A. L.; Saginaw Valley State University; *clflorey@svsu.edu*

Effects of bupropion, an environmental contaminant, on a keystone aquatic species (Orconectes rusticus)

Bupropion is an atypical antidepressant commonly prescribed in human medicine for the treatment of clinical depression and other mood disorders. Bupropion present in wastewater and hospital effluent has been shown to affect prey behavior of fish, reduce distress in rats, and increase aggression in mice. In order to further examine the effects of this chemical, this study aims to quantify foraging behavior and aggression of crayfish (*Orconectes rusticus*), a keystone species, when exposed to environmentally relevant concentrations. Crayfish were exposed to varying concentrations (0, 25, 50, 100, and 200 ng/L) of bupropion for 48 hours. For each exposure level, 10 foraging trials were conducted (1 crayfish per trial). Crayfish were acclimated to a Y-maze for 5 minutes, after which they had 15 minutes to move through the maze and seek the source of a food odor. Duration of time spent in each section of the y-maze was quantified. Effects on agonistic interactions were also examined with 10 aggression trials for each exposure level (2 crayfish per trial). The pair acclimated to opposite sides of a divided tank for 10 minutes; the divider was then removed and the crayfish were allowed to interact for 15 minutes. Agonistic encounters were quantified using a modified ethogram to score intensity of aggression and determine encounters' winners and losers. Preliminary data of foraging and aggression trials is being analyzed with ANOVAs to assess crayfish aggression and foraging in order to demonstrate the effects of bupropion on an aquatic invertebrate. The effects that bupropion have on crayfish behavior could negatively impact its role as a keystone species in aquatic ecosystems.

P3.215 FLYNN, CM*; PUZEY, JR; College of William and Mary; *cflynn2013@gmail.com*

A Comparative Study of the Biomechanics of Coiling Tendrils

Many plant species exhibit tendrils that, after attaching to a fixed point, coil into a helical structure. The ‘muscle' of tendrils are gelatinous fibers (g-fibers). G-fibers, also found in reaction wood, have been shown to drive tendril coiling. Although these g-fibers are common in species with coiling tendrils, the coil of tendrils from different species are morphologically distinct (be it through handedness, presence of helical perversions, or other). This study takes a comparative approach to examine two things: (1) the role of gelatinous fibers in driving tendril coiling in independently evolved climbing plants; and (2) the relationship of gelatinous fibers to the mechanical properties of the resulting tendril. We expect that there will be a marked difference between different species' morphology that can be directly correlated to variations in their movement. In particular, we believe that the pattern of cellulose banding in the gelatinous fiber will have a significant effect on the tendril's coiling habits and mechanical properties in each species. Knowledge of the coiling structures of tendrils can help further not only a better understanding of plant movement but also a more advanced biomimetic spring that may have real-world applications.

28.1 FLYNN, RW*; THOMPSON, K; MAYER, GD; LANCE, SL; University of Georgia, Odum School of Ecology, Texas Tech Univ. Department of Environmental Toxicology, University of Georgia, Savannah River Ecol Lab; *rwf130@uga.edu*

Response of Amphibian Gut Microbiome to Coal Combustion Waste

Gut microbial communities play critical roles in metabolism, immune function, and physiology and are shaped by host genetics and environmental factors, including contaminants. Coal combustion represents the largest source of energy and generates toxic waste products. These coal combustion wastes (CCW) are usually stored in landfills and surface impoundments that are appealing habitats for wildlife as they provide permanent sources of freshwater. However, they also contain toxic levels of trace elements, thus putting organisms in direct contact with contaminants. We examined the relative influences of parentage and environmental contaminants on the gut microbiomes of the southern toad (*Anaxyrus terrestris*). We fertilized eggs from two female toads with sperm from eight males and reared the larvae through metamorphosis in their natal CCW impoundment and in a nearby reference wetland with no history of contamination. Sequencing of the 16S marker gene was used to analyze gut bacterial diversity and population structure within the different gut communities compared to several phenotypic measures. Species richness and diversity were negatively correlated with developmental time (r = =-0.21, -0.19) and positively correlated with growth rate (r = 0.28, 0.27). The identity of the female parent had a significant effect on richness and diversity. Beta diversity was related to rearing environment, developmental time, and female parent within environment. Species richness was greater in the guts of individuals reared in the contaminated environment. These results suggest that host gut microbial diversity could influence fitness related traits and that the role contaminants play in shaping these communities is complex.

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VASA Expression Shows Unusual Variation in the Tailless Ascidian Molgula occulta.

Ascidians are invertebrate chordates that share a number of developmental features in common with the vertebrates including a branchial basket, an endostyle, and a notochord inside a functional swimming larval tail. During typical ascidian development 10 notochord precursor cells divide twice to make 40 cells and then converge and swell to extend out a functional swimming tail. The Molgulids are a monophyletic clade of ascidians in which a tailless phenotype has evolved multiple times independently. Here we investigate the differential gene expression of two species of molgulids, *Molgula oculata* and *Molgula occulta*. *Molgula oculata*, has the tailed phenotype, but its sister species, *Molgula occulta*, has lost the tail and notochord, developing 20 notochord cells that do not converge and extend. The two species can be hybridized: if the egg of the tailless species is used, then some of the resulting hybrids have 20 notochord cells that do converge and extend into a short, non-functional half tail. We have sequenced the genomes and embryonic developmental transcriptomes of these two sister species as well as hybrid embryos, and are searching for differential gene expression of known notochord related genes to attempt to identify the developmental changes responsible for the loss of the tailed phenotype. We are using the transcriptomes to identify the potential genes, then using qPCR to verify expression and *in situ* hybridization to visually confirm spatio-temporal expression. Thus far VASA *in situ* hybridization has revealed variation in cellular positions as early as gastrulation and premature cell divisions of the germ line progenitors after neurulation in the tailless *M. occulta* embryos.

P2.191 FOLKS, NY*; CRUZ, P; HRANITZ, J; BARTHELL, J; GONZALES, VH; University of Texas at El Paso, Montclair State University, Bloomsburg University, University of Central Oklahoma, University of Kansas; *nyfolks@miners.utep.edu*

A Field Test of the Pollinator Pesticide Avoidance Hypothesis in Fallow Agricultural Fields

Prior research by our group has investigated the pesticide avoidance hypothesis for pollinators in urban and agricultural habitats using pan trap studies. These and other studies suggest that insect taxa differ in their orientation (attraction, avoidance, or neutral) toward pan traps containing neonicotinoids or pyrethroids and, therefore, the effects of pesticides may be intensified or moderated by behavior of some taxa. For this experiment, we examined the effect of an agricultural dose rate reported for sunflowers of Confidor SC 350 (a commercial formulation of imidacloprid) on insects visiting natural vegetation found in fallow agricultural fields in Canakkale, Turkey. We used a before-after experimental design on 15 1-M2 plots arranged in three rows each of five plots. All plots were separated from adjacent plots by 2 meters. Pollinator visitation was monitored during antithesis for 5 minutes per plot hourly, beginning at 7:30 and ending at 13:30 daily. The total number of insect visits per plot was recorded during each observation period. The total number of pollinator visits decreased after the application of the Confidor SC 350. This result generally supports the pesticide avoidance hypothesis but future analysis of taxa-specific responses to the treatment.

P1.101 FOOTE, S*; MONHART, M; YEE, S; MAUCH, E; SCHREIBER, AM; St Lawrence University, NY; *aschreiber@stlawu.edu*

Thymus gland remodeling during natural and hormone-induced Xenopus laevis metamorphosis

Anuran metamorphosis is modulated by the synergistic actions of thyroid (TH) and glucocorticoid hormones. Metamorphosis is accompanied by immune system remodeling as larval antibodies are replaced by a new adult repertoire. Although glucocorticoids have been shown to induce thymus lymphocyte cell death, the influence of TH on thymus remodeling remains unknown. Here we profile changes in thymus gland cell proliferation (immunoreactivity against phosphohistone H3; PH3) and apoptosis (immunoreactivity against active caspase-3) during natural metamorphosis, and also following treatment with TH (5 nM T3) and/or dexamethasone (Dex, 2 uM) for 48 hours. Natural metamorphosis was accompanied by a doubling of thymus size from late prometamorphosis (NF57) through the end of metamorphic climax (NF66). Peaks in caspase and PH3 immunoreactivity occurred at early (NF 60) and late climax (NF 62), respectively. Treatments of premetamorphic (NF 50) or prometamorphic (NF 56) tadpoles with either TH or Dex alone increased caspase immunoreactivity, with Dex+TH in combination producing the highest response. Compared with prometamorphic controls, Dex treatment alone or in combination with T3 doubled PH3 immunoreactivity, whereas T3 alone quadrupled the amount of signal. Taken together, our findings suggest that both glucocorticoids and TH each contribute to thymus cell proliferation and apoptosis during metamorphosis. However, whereas glucocorticoids suppress both larval and adult thymocytes, we hypothesize that T3 functions to suppress larval thymocytes, but promotes the proliferation of adult thymocytes.

S6.2 FORLANO, P.M.; CUNY Brooklyn College and Graduate Center; *pforlano@brooklyn.cuny.edu*
Roles for dopamine in peripheral auditory sensitivity and motivation for mate localization in a vocal fish
Plasticity in sensory and motor circuitry underlies dramatic changes in seasonal reproductive behaviors across vertebrates. In female midshipman fish, seasonal, steroid-dependent plasticity in the auditory periphery functions to better encode frequencies of the male advertisement call. In addition, females are only motivated to respond and attend to advertisement calls when filled with mature eggs. Our recent investigations support brain-derived catecholamines, dopamine in particular, as important neuromodulators linking seasonal changes in audition with behavioral responsiveness to acoustic social signals in midshipman fish. Diencephalic dopaminergic (DA) neurons were found to directly innervate the inner ear and its cholinergic efferent nucleus in the hindbrain. Based on our prediction from seasonal changes in DA innervation of both these areas, we hypothesized an inhibitory effect of DA on the peripheral auditory system. Indeed, pharmacological studies combined with physiology demonstrate a robust inhibition by DA in the inner ear. These data suggest that an increase in auditory sensitivity during the reproductive period results from a release of DA inhibition. We also tested the hypothesis that females who exhibit a robust behavioral response to the male advertisement call would display elevated levels of neural activity within catecholaminergic neurons as measured by the immediate early gene product cFos. Three forebrain DA nuclei show increased cFos activation with time spent attending to a playback of the mate call. Neuroanatomical, physiological and behavioral evidence support diencephalic DA neurons as ideal candidate neuromodulators which function to integrate the detection and appropriate motor response to conspecific acoustic signals for successful reproduction.

P2.108 FORSBURG, Z.R.*; KIM, D.S.; GABOR, C.R.; Texas State University; *zrf5@txstate.edu*
Is artificial light at night a stressor for Barton Springs salamander, Eurycea sosorum?
Artificial light at night (ALAN) is defined as artificial light that alters the natural light dark patterns in ecosystems. ALAN can have a suite of effects on community structure and is a driver of evolutionary processes that influences a range of behavioral and physiological traits. Research on the effects of ALAN on amphibians is lacking and is important as ALAN could contribute to stress and declines of these populations, particularly in urban areas. We tested the hypothesis that exposure to constant light would induce a stress response in *Eurycea sosorum*. We exposed adult *E. sosorum* to either constant light or a natural light regimen for 14 days. We used water-borne hormones to measure corticosterone (CORT) release rates after two days of exposure and at the end of the experiment. We found a time by treatment interaction with individuals in the control having higher CORT release rates than in constant light on day 2, on day 14 the CORT went down for the control treatment but didn't change for the ALAN treatment. These results could suggest that the salamanders were stressed by the process of relocating and while the control group was able to mount a stress response, the potential stress of constant exposure to light may have caused a disruption of the HPA axis in the ALAN treatment salamanders. Overall these data suggest that ALAN can affect CORT levels in *E. sosorum*, but further investigation is needed to fully understand how ALAN may interact with additional stressors.

P1.148 FORSMAN, AM*; PERALTA-SANCHEZ, JM; WINKLER, DW; KNIGHT, R; ANGERT, ER; Cornell Univ., Univ. Granada, Spain, Univ. of California, San Diego; *amf226@cornell.edu*
Bird-Bed Bugs: evaluating the effects of abundance vs. diversity of nest-dwelling bacteria on maternal deposition of egg yolk antibodies in wild tree swallows
Female birds transfer immunoglobulin Y (IgY) to their eggs, which confer beneficial maternal effects on offspring growth and immune function. The specificities of these antibodies reflect the antigenic environments that females have experienced and likely correspond to antigenic challenges that offspring will encounter. Thus, females should be selected to deposit yolk IgY in accordance with antigenic pressure in the offspring environment. We have previously shown that active bird nests harbor diverse bacteria and that breeding birds respond to experimental modifications of these communities as evidenced through differential levels of maternal antibody deposition. Here we present results from a direct side-by-side test of the Antigen-Diversity and Antigen-Abundance Hypotheses to determine how each of these community characteristics contributes to variation in the total amount of yolk IgY deposited by female tree swallows (*Tachycineta bicolor*). Swallows exposed to reduced bacterial diversity during nest-building produced eggs and nestlings with lower levels of IgY than did control females, lending support to the Antigen-Diversity Hypothesis; nestlings from diversity-reduced nests also had lower plasma bactericidal activity than did control nestlings. However, we did not find support for the Antigen-Abundance Hypothesis because IgY levels of eggs and nestlings did not differ significantly between abundance-reduced and control groups. We also provide an overview of nest microbiome structure from metabarcoding data produced by Illumina sequencing of the 16S rRNA gene.

128.5 FOSTER, KL*; HIGHAM, TE; Univ. of Ottawa, Univ. of California, Riverside; *kfost001@ucr.edu*
Comparative neuromuscular function during arboreal locomotion in Anolis lizards
Anolis lizards are a model system for how microhabitat can shape morphology, ecology, and behavior of individuals and communities. It is believed that the *Anolis* ecomorphs of the Greater Antilles are specialized for specific regions of the arboreal habitat because of differences in the locomotor demands inherent to each region. However, despite the fact that muscles are primarily responsible for powering their locomotion, it is unclear whether the physiology or control of these muscles varies between ecomorphs to facilitate this specialization. Using synchronized electromyography and high-speed video of animals running on broad and narrow perches inclined at 0º, 30º, and 90º, we examine the activity patterns of four fore- and hind limb muscles in five *Anolis* species: *A. evermanni* and *A. carolinensis* (trunk-crown ecomorph), *A. cristatellus* and *A. gundlachi* (trunk-ground ecomorph), and *A. equestris* (crown giant ecomorph). Overall, all species tend to have greater levels of motor unit recruitment on steeper inclines than on level surfaces. Similarly, activity of the puboischiotibialis generally increased on narrow surfaces compared to broad surfaces in all species. However, there are some key differences between species. For example, gastrocnemius activity was generally equal or slightly elevated on the narrower surface compared to the broad surface in trunk-ground species, whereas recruitment tended to decrease on the narrow surface compared to broad surface in trunk-crown and crown-giant species. These data will significantly advance our understanding of how neuromuscular function can become specialized to allow successful locomotion in the *Anolis* ecomorphs, as well as providing insights into behavioral sources of muscle plasticity.

102.7 FOSTER, SA; Clark University, Worcester MA; *sfoster@clarku.edu*

Distinguishing Novelty from Re-emergence of Ancestral Behavioral Traits: Insights from an Adaptive Radiation

Evolutionary novelty is particularly difficult to define and demonstrate- a problem that is exacerbated by the possibility that ancestral phenotypes unexpressed over evolutionary time frames can re-emerge as environments change. The re-emergence of ancestral traits can be difficult to discriminate from the evolution of true novelties unless the ancestral condition can be identified, and ideally, experimental manipulation can be used to elicit the ancestral phenotype or one sufficiently similar that homology is likely. The adaptive radiation of the threespine stickleback fish, Gasterosteus aculeatus, offers an unusual opportunity to explore the possibility that behavioral traits, apparently lost from certain derived populations, can re-emerge under conditions approximating those to which oceanic ancestors were exposed. Specifically, as oceanic stickleback invaded freshwater habitats following the last glacial retreat, populations that invaded lakes most suited to planktivory appear repeatedly and independently, to have lost ancestral expression of cannibalism and a diversionary display that males use to defend young in nests from cannibalistic conspecifics. These plastic behaviors have been re-elicited in one population as a consequence of recent productivity transitions in one lake, and can be elicited in other populations, though the threshold for eliciting the behavior is higher than in populations in which the behaviors persist. I discuss the importance of this phenomenon further using additional, more ancient examples.

70.3 FOX, C.H.*; SUMMERS, A.; GIBB, A.C.; BEMIS, W.E.; Cornell University, Friday Harbor Laboratories, Northern Arizona University; *chf7@cornell.edu*

Flatfish Benthic Walking: a new vertebrate gait

Many benthic fishes move along the bottom with a bipedal or punting gait of the paired pelvic or pectoral fins. We examined the benthic gaits of flatfishes (six species, total n=34) which use the dorsal and anal fin to move along the substrate to (1) better understand the functional and evolutionary morphology of this system and (2) compare flatfish gaits to those based on paired appendages and cilia. All flatfish species employed one or more benthic gaits, which we termed "walking" and "bounding". Two flatfish species, the Pacific sand sole, *Psettichthys melanostictus* (N=5) and the English sole, *Parophrys vetulus* (N=5) were selected for additional gait analyses. We found that walking is consistently used as a form of benthic locomotion in *Psetticthys melanostictus*, while bounding is preferred by *Parophrys vetulus*. We tracked points on the head and leading edge of the fin wave from videos (120 fps) using the DLTdv5 Digitizing Tools for MATLAB and the Manual Tracking plugin for ImageJ. During bounding, a single wave of median fin propulsion is assisted by lateral undulations of the body and tail, producing rapid but intermittent acceleration of the body. During walking, flatfishes use sequential portions of their median fins as "feet" that move in parallel waves to propel their bodies across the substrate at a constant velocity. To complete a walk cycle, a fin ray swings up off of the substrate, protracts and converges with neighboring fin rays to form a functional "foot". The fin ray "foot" then pushes down and back, and the wave progresses posteriorly to produce forward movement of the body. The waves of the median fin rays appear broadly similar to the metachronal waves observed in millipede legs and the cilia of paramecium; to our knowledge this is the first example of metachronal waves producing a vertebrate walking gait.

P1.107 FRAGATA, AE*; POKU, Y; GRAHAM, MA; FOSTER , SA; BAKER, J; Clark University; *afragata@clarku.edu*

The influences of biogeography and maternal stress on early life characteristics in threespine stickleback (Gasterosteus aculeatus)

Performance in early life is predictive of individual survival and reproductive success. Here we take advantage of the broad geographical range inhabited by the threespine stickleback, *Gasterosteus aculeatus*, to consider how ecological factors might shape early life characteristics over evolutionary time. Additionally, with the application of maternal stressors, we investigate the extent to which offspring growth and behavior are plastically influenced by maternal condition. Both lab-reared and wild-caught parents were studied, representing populations in British Columbia and Alaska. Lab-reared mothers received one of four treatments: acute stressor at ovulation, chronic stressor throughout clutch production, post-ovulatory egg retention (an ecologically relevant challenge) or minimal handling time at ovulation (control). Wild-caught mothers were subjected to either an acute stressor or the control treatment. Fry were reared under identical conditions and assayed for growth and feeding performance during the first three weeks post yolk absorption. Geographic region had the largest effect on these traits; relative to individuals from British Columbia, fry from Alaskan populations grew faster and were able to consume a greater number of food items per unit time. Our results suggest that there is selection for these distinct regional patterns due to differences in climate, particularly in the severity and length of the winter seasons, which favors high consumption rates and fast growth to reach a critical size for successful over-wintering. We discuss how early life traits are affected by maternal stressors, ecological conditions, including predation presence and salinity, parental rearing environment, and interactions between these factors.

P3.195 FRANCIS, R. A.*; WOODWARD, A.R.; MOORE, B.C.; Sewanee: The University of the South, Florida Fish and Wildlife Conservation Commission; *francra0@sewanee.edu*

Morphology Changes in Alligator Phallic Glans via Artificial Inflation

The distal glans of the *Alligator mississippiensis* phallus is an inflatable structure that engorges to form a cup-like shape during copulation to putatively facilitate effective gamete transfer and increase fertilization probability. Previous research has demonstrated the presence of extensive cavernous vascular spaces in the glans tissues that engorge via increased blood flow through paired vessels running the length of the ventral phallus. Here we exploit these blood vessels to artificially inflate the glans tissues and quantitatively measure the shape change during this transition from flaccid to copulatory states. Using dissected necropsy tissues, we inflated the tissues using fluid pressure created through a needle and formalin-filled syringe while impeding back flow out the phallus by ligating the base. 3D wireframes of glans tissues before and after inflation were acquired using 123D Catch (Autodesk). Tissue expansion was measured by assessing distance changes between given tissue landmarks and calculating wireframe volumes. A better understanding of how the alligator phallus achieves a copulatory state lays the foundation for later study of how this morphology interfaces with female cloacal tissues and facilities insemination.

P2.195 FRANCO, RWA*; DI BENEDITTO, APM; Universidade Estadual do Norte Fluminense; *robertofrancobr@gmail.com*

Otoliths of Sciaenidae fish: comparison of composition by electron paramagnetic resonance

Otoliths are crystalline structures of calcium carbonate located inside the inner ear of teleost fish that are responsible for balance in the water column and hearing. These biominerals grow via deposition of calcium carbonate, becoming a crystalline structure of vaterite, calcite or aragonite. Spectra of Mn2+ were applied to verify geographic variations among three stocks of Sciaenidae fish in southeastern Brazil: Paralonchurus brasiliensis, Stellifer rastrifer and Isopisthus parvipinnis. Similar spectra shape and zero-field splitting D (22.4 mT) indicated that biocrystallization process is the same for all fish species, even under different environmental conditions. Interspecific differences in Mn2+ concentration were detected regarding the otolith shape: elongated otoliths, as found in P. brasiliensis, have higher manganese concentrations compared to rounded otoliths, as in S. rastrifer amd I. parvipinnis. Geographic variations among the stocks of the three fish species could be detected. Fish stocks under riverine influence have less Mn2+ concentration than ones under marine influence. Manganese detection via this technique (electron paramagnetic spectroscopy) is a non-destructive approach to fish stocks studies.

70.4 FRANK, TM*; HEDRICK, BP; DODSON, P; University of Pennsylvania, University of Massachusetts, Amherst; *tfrank@sas.upenn.edu*

Correlating Avian Hindlimb Function and Pelvic Morphology with 2-D Geometric Morphometrics

A dramatic range of morphologic variation can be found within the basic avian body plan, a product of birds' radiation into nearly 10,000 extant species that occupy a diverse set of niches. The great ecological diversity of birds is particularly apparent in terms of the remarkable variety of locomotor strategies they employ, from nimbly hovering hummingbirds and soaring albatrosses to deep-diving auks and cursorial ostriches. To assess how diversification of locomotor modes has impacted the evolution of avian pelvic morphology, we conducted a 2D geometric morphometric analysis of bird pelves from 165 species ($n = 263$) across all Aves. Pelvic morphology was captured by placing landmarks and semilandmark curves on photographs of the ilium and ischium of each specimen, in separate dorsal and lateral analyses. The bird species were categorized by locomotor group to determine how morphologic variation is related to hindlimb function. We found that the locomotor categories were significantly discriminated in morphospace ($F = 15.903$, $p = 0.001$). Phylogeny was also significantly correlated with shape ($K = 0.409$, $p = 0.001$), but in phylogenetically-corrected analyses functional grouping remained significant ($F = 4.61$, $p = 0.008$). Birds adapted for hindlimb-propelled swimming were particularly differentiated, with narrow, highly elongated ilia. Hyperaerial birds such as hummingbirds and swifts grouped at the opposite end of morphospace, with relatively squat pelves. Other locomotor groups plotted at various points between these two extremes of form and function, suggesting that iliac elongation in Aves reflects an increase in functional attachment area for hip musculature.

79.6 FRANKLIN, AM*; DONATELLI, CM; TYTELL, ED; Tufts University, Medford, MA; *amanda.franklin@tufts.edu*

Sparring Stomatopods: Do Colored Patches Signal Fighting Ability?

Many animal characteristics have evolved to facilitate intraspecific communication. Deciphering what information these signals convey to a receiver is essential if we are to understand these signaling systems. Stomatopods are marine crustaceans that live in burrows, and are recognized by two punching arms capable of inflicting damaging blows. On each punching arm is a colored patch called the meral spot. During contests over ownership of burrows, stomatopods can use the meral spots to assist with opponent assessment. In *Neogonodactylus oerstedii* stomatopods, both the luminance and UV reflectance of the meral spots are used in contests; however, we do not know what information these spots convey to the receiver. Previous research has demonstrated that in *N. oerstedii* stomatopods, darker meral spots are correlated with larger meri (the segment of the punching arm where the meral spot is located). Furthermore, merus size is associated with strike force in other stomatopod species. We hypothesized that the meral spot transmits information about fighting ability, or Resource Holding Potential (RHP), to an opponent. To investigate this, we recorded strike force, and spectra of the meral spot for *N. oerstedii* individuals in the lab. We discuss whether these variables correlate, and the implication for stomatopod signaling systems and contests. This research addresses a key question in animal communication research - what are animals ‘saying' to one another?

S10.8 FRöBISCH, NB*; BICKELMANN, C; LIMA, G; TRIEPEL, S; KAWAGUCHI, A; SCHNEIDER, I; Museum für Naturkunde, Leibniz Institute for Evolution and Biodiversity Science, Museum für Naturkunde, Leibniz Institute for Evolution and Biodiversity Scienc, Center of Regenerative Therapies Dresden, Universidade do Para, Belém, Brazil; *nadia.froebisch@mfn-berlin.de*

Evolution and development salamander limbs

Among extant tetrapods, salamanders are unique in showing a reversed, preaxial polarity in patterning the skeletal elements of the limbs, which is particularly striking considering that tetrapod limb development is otherwise a rather conservative process. Data from the fossil record show that preaxial polarity in limb development was present in various Paleozoic temnospondyl amphibians, among them in the 290 Ma old dissorophoids *Apateon* and *Micromelerpeton*, which are likely stem representatives of modern amphibians. However, preaxial polarity was also identified in the coeval but much more distantly related stereospondylomorph *Sclerocephalus*. On the contrary, ontogenetic data from lepospondyl ‘microsaurs', which are considered more closely related to amniotes than to temnospondyls, indicate that unlike temnospondyls, they likely had postaxial polarity in limb ossification. The paleontological data suggests that preaxial polarity in limb development is not a derived feature of modern salamanders, but rather evolved very early in tetrapods in the lineage leading towards modern amphibians. Developmentally, expression of genes of the Shh pathway and of the Hox cluster in the Mexican axolotl *Ambystoma mexicanum* indicate a canonical expression of genes in the early phase of limb development. However, patterns of expression deviate from typical tetrapod expression patterns in the late phase, suggesting that salamander specific features of limb development may occur mainly in later phases of limb development.

3.4 FRECKELTON, ML*; NEDVED, BT; HADFIELD, MG; University of Hawaii at Manoa; *marnief@hawaii.edu*

Multiple Bacterial Cues Induce Larval Invertebrate Settlement

Larvae of the serpulid polychaete *Hydroides elegans* can be induced to metamorphose by monospecific biofilms of a number of bacterial species. Detailed investigations into the nature of the settlement cue produced by the bacterium *Pseudoalteromonas luteoviolacea* have established bacteriocin aggregates (or MACs) as the metamorphic cue by this bacterium. In our study, three additional inductive bacterial species, *Cellulophaga lytica*, *Bacillus aquimarus* and *Staphylococcus warneri*, were investigated to determine if they produce similar products. Genomic comparisons of these bacteria revealed that their metamorphic activities are not due to the presence of the same genetic machinery as *P. luteoviolacea*. Active biofilm cell densities differed between the strains and metamorphic activity was found in the 0.22 µm filtrate in direct contrast to MACs of *P. luteoviolacea*. In *C. lytica*, negatively stained TEM images confirmed the lack of MAC structures and instead revealed the presence of vesicles. Further TEM imaging confirmed that these vesicles budded from the surface of *C. lytica* in a manner consistent with outer membrane vesicles. Equivalent TEM analyses of *S. warneri*, however, did not reveal the presence of either MACs or vesicles. It is likely that the ability of *H. elegans* to respond to multiple bacterial biofilm products greatly increases its larva's ability to find and settle on appropriate surfaces with differing bacterial communities.

P1.2 FREDERICH, M.*; FLEFEL, I.; ROESE, U.; BYMERS, L.; ZEEMAN, S.; Univ. of New England, Biddeford; *mfrederich@une.edu*

TURBO: The Undergraduate Saco River Biodiversity Observatory; an LTER-style research experience to enhance STEM education

STEM education is becoming increasingly important for succeeding in a society that depends on science and technology. However, STEM persistence rates in undergraduate programs are low, nationally in the range of 40%. A pedagogical shift towards more experiential, project-based education has shown to be successful in increasing STEM persistence rates, enhancing understanding of science, and increasing student's motivation to learn. Building on a strong track record in undergraduate research we are implementing a place- and theme-based interdisciplinary project that spans all 4 years of undergraduate education in all STEM majors. We use our location at the mouth of the Saco River and the surrounding ecosystem as the overarching theme. Multiple existing lab activities and field trips in Biology, marine biology, environmental science, chemistry and physics are focused on the Saco River Ecosystem and new activities are implemented to investigate in an LTER-style the fresh and seawater systems surrounding the campus. Students collect data on water parameters, invertebrates, fish, algae, plankton, marsh diversity, plants, invasive species, and more. All data are available to students and faculty in a central database. Statistics courses will use student-generated data to show the applicability of the respective tests. Overall, we increase student engagement, satisfaction, and excitement for STEM and are working on assessing the respective impact on student retention. This place- and project-based interdisciplinary approach can be used as a blueprint for other programs and schools. Funded by NSF grant# DUE-IUSE 1431955.

66.4 FREDERICH, B*; SANTINI, F; KONOW, N; LECCHINI, D; ALFARO, ME; University of Liège, Liège, Associazione Italiana per Studio Biodiversita', UMass., Lowell, CRIOBE, Moorea, French Polynesia , Univ. of California, Los Angeles; *bruno.frederich@ulg.ac.be*

Patterns of Body Size and Shape Diversification in Marine Angelfishes (Pomacanthidae)

The Pomacanthidae is an iconic reef fish family of about 88 species. They occupy a diverse range of trophic niches (e.g. spongivory, algivory, zooplanktivory) and show habitat partitioning (e.g. cryptic, pelagic species). The pomacanthids reach disparate body form, with large body sized species (e.g. 30-45 cm of Total Length - *Pomacanthus* spp) and a paraphyletic group of 34 pygmy angelfishes (e.g. 7-12 cm TL - *Centropyge* spp). To the best of our knowledge, the hypothesis that size variation in Pomacanthidae is adaptive and the potential correlation between size and overall body shape optima has never been tested in a quantitative evolutionary framework. Here, we tested these hypotheses using a novel time-calibrated phylogeny, eco-morphological data and phylogenetic comparative methods. The method SURFACE allowed the detection of three adaptive peaks in the body size space, one of them referring directly to the pygmy angelfishes (θ_{pygmy} = 11 cm TL). Firstly, we found no evidence of evolutionary allometry across angelfishes (PGLS analysis; P-value = 0.12). Secondly, in order to detect the major driving force of overall body shape in angelfishes, we compared the fit of Brownian motion (BM) and Ornstein-Uhlenbeck (OU) models that allow for different optimal shapes according to size, diet and habitat partitioning. Counter to our simple prediction of size and ecological determinants of body shape, a single-optimum OU model produced the best fit. Overall, our results show that the drivers of size diversity may differ from the ones of body shape.

14.4 FREEDMAN, C; FUDGE, DS*; University of Guelph, Chapman University; *fudge@chapman.edu*

Hagfish Houdinis: Biomechanics and Behavior of Squeezing Through Small Openings

Hagfishes are able to squeeze through small openings to gain entry to crevices, burrows, hagfish traps, and carcasses, but little is known about how they do this, or what the limits of this ability are. In order to describe this ability, and to investigate possible mechanisms by which it is accomplished, we analyzed videos of Atlantic hagfish (Myxine glutinosa) and Pacific hagfish (Eptatretus stoutii) moving through narrow apertures in the lab. We investigated the hypothesis that the passive movement of blood within a hagfish's flaccid subcutaneous sinus allows it to squeeze through narrower apertures than it would be able to if it were turgid. To test this hypothesis, we measured changes in body width as the animals moved through narrow openings, and documented the behaviors associated with this ability. We found that hagfishes are able to pass through narrow slits that are less than one third the width of their bodies. Our results are consistent with the idea that a flaccid subcutaneous sinus allows hagfish to squeeze through narrow apertures by facilitating a rapid redistribution of venous blood. In addition, we describe nine distinct behaviors associated with this ability, including a form of non-undulatory locomotion also seen in snakes and lampreys. These results have relevance for the hagfish trap fishery and they illuminate a behavior that may be a critical component of the hagfish niche, due to its likely importance in feeding and evading predators.

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Trade-offs in ecoimmunology: Costs for individuals and populations

The immune system is a critical component of health and fitness, whereby organisms must maintain sufficient health to survive to reproduce. Because of the key role of immunity in an organism's fitness, the use of immunological indices is widespread. However, there is a paucity of empirical support for the best way to interpret immunological data, and the internal energetic state of the organism, as well as the external environmental pressures it faces, are often not considered concurrently. Presently, a more robust immune response is thought to be advantageous, regardless of context. In reality, a "weaker" response may ultimately lead to improved fitness if the animal incurs fewer performance costs on competing systems, especially reproduction. To determine the fitness consequences of immunity, individual immunity and reproduction must be linked to population performance. A synthesis of results will be presented using a well-studied model organism, the side-blotched lizard, from a combination of field and laboratory studies to test the hypothesis that resource availability alters energy allocation among the immune and reproductive systems. Specifically, experiments involving specific immune and reproductive metabolic and performance costs in a laboratory setting will be discussed, as well as associated demographic trade-offs between survival and reproductive success, demonstrating essential links between immunity and the population.

24.2 FREYMILLER, G.A.*; WHITFORD, M.W.; HIGHAM, T.E.; CLARK, R.W.; San Diego State Univ. and Univ. of California, Riverside, San Diego State Univ. and Univ. of California, Davis, University of California, Riverside, San Diego State University;
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Kangaroo Rat Acrobatics: How to Dodge a Rattlesnake Strike

Predator evasion strategies are essential for understanding the coevolution between predator and prey, and the pressures that drive the diversity in morphology and behavior. The unique morphology and performance of kangaroo rats give them the ability to leap out of the path of a striking predator with incredible agility and power. When attacked by a rattlesnake, they use their disproportionately large hind limbs to create a powerful, extremely rapid jump accompanied by acrobatic twists that carry them out of the strike trajectory. We first examined the behavioral and biomechanical aspects underlying the evasive maneuvers of desert kangaroo rats (*Dipodomys deserti*) in response to simulated strikes (using a cannon apparatus) to further elucidate the evasive abilities of kangaroo rats. We compared the responses of vigilant and non-vigilant kangaroo rats to determine if and how behavioral states can modify performance. We found that vigilant kangaroo rats outperformed non-vigilant kangaroo rats across all examined variables. This research also suggests that the performance of desert kangaroo rats is even exceptional in comparison to other animals preyed upon by snakes, such as ground squirrels. Second, we used high speed cameras to capture the evasions of desert kangaroo rats to natural sidewinder rattlesnake (*Crotalus certastes*) strikes in the field. This compliments the simulated snake trials by allowing us to understand the complex maneuvers that occur under natural conditions. We compared the evasive maneuvers that resulted in successful evasions (N=18) to those that resulted in a successful snake strike (N=14). This integrative and multidimensional examination of predator evasion strategies in nature will propel our understanding of predator-prey dynamics.

135.4 FRIEDER, CA*; APPLEBAUM, SL; PAN, T-CF; HEDGECOCK, D; MANAHAN, DT; University of Southern California; *cafriede@usc.edu*

Energy Metabolism and Shell Formation in Bivalve Larvae under Different Environmental Conditions

Many marine organisms produce biomineralized structures for morphological support and protection. In this study we focused on shell formation during early larval development of the Pacific oyster, *Crassostrea gigas*. Following fertilization, most of the change in total mass during the first ~48 hours of development was due to increased inorganic shell mass. During this same period of development, about half of total respiration was accounted for by the energy cost of protein synthesis and sodium-potassium transport (Na^+,K^+-ATPase). The remainder of a larva's energy budget could contribute to the energy cost calcification. Regardless of whether larvae were cultured under environmentally favorable conditions for calcification (i.e., seawater saturated with respect to aragonite) or unfavorable conditions (seawater undersaturated with respect to aragonite), larvae utilized similar amounts of energy to complete early development to the first shelled stage (veliger). Defining changes in cellular energy allocation is a promising approach for understanding the impact of environmental change on marine organisms.

29.5 FRIEDMAN, SF*; PRICE, SA; HOEY, AS; WAINWRIGHT, PC; Univ. of California, Davis, James Cook University;
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Ecomorphological Convergence in Planktivorous Surgeonfishes

Morphological convergence plays a central role in the study of evolution. Often induced by shared ecological specialization, homoplasy hints at underlying selective pressures and adaptive constraints that deterministically shape the diversification of life. Though midwater zooplanktivory has arisen in adult surgeonfishes (family Acanthuridae) at least four independent times, it represents a clearly specialized state, requiring the capacity to swiftly swim in midwater locating and sucking small prey items. While this diet has commonly been associated with specific functional adaptations in fishes, acanthurids present an interesting case study as all other species feed by grazing on benthic algae and detritus, requiring a vastly different ecomorphology that emphasizes biting behaviors. We examined the feeding morphology in 30 acanthurid species and, combined with a pre-existing phylogenetic tree, compared the fit of evolutionary models across two diet regimes: zooplanktivores and non-zooplanktivorous grazers. Accounting for phylogenetic relationships, the best-fitting model indicates that zooplanktivorous species are converging on a separate adaptive peak from their grazing relatives. Driving this bimodal landscape, zooplanktivorous acanthurids tend to develop a slender body, reduced facial features and weakened jaw adductor muscles. However, despite these phenotypic changes, model fitting suggests that lineages have not yet reached the adaptive peak associated with plankton feeding even though some transitions appear to be over 10 million years old. These findings demonstrate that the selective demands of pelagic feeding promote repeated — albeit very gradual — ecomorphological convergence within surgeonfishes, while allowing local divergences between closely related species, contributing to the overall diversity of the clade.

142.2 FUESS, LE*; MANN, WT; BRINKHUIS, V; STACY, C; MYDLARZ, LD; Univ. of Texas Arlington, Florida Fish and Wildlife Conservation Commission; *fuess@uta.edu*

Octocorals demonstrate fitness tradeoffs associated with response to a disease outbreak

Octocorals are predicted to dominate reefs under increasing environmental stress, largely due to their ability to better resist both abiotic and biotic stressors. In the fall of 2014, an unknown disease was observed affecting octocorals of the genus *Eunicea* on reefs near Florida's coast. Signs of the disease were dark black appearance, indicative of heavily melanization of the tissue. To determine the immune response of these corals, fragments of healthy and infected colonies of *Eunicea calyculata* from the Florida coast were collected in fall of 2014 and analyzed using RNAseq analyses and biochemical immune assays. RNAseq data was analyzed for differential expression patterns using Cufflinks and co-expression groups were identified using the R package WGCNA. Differential expression analyses revealed that genes up regulated in diseased colonies were enriched for processes involved in adhesion and cell signaling, while downregulated genes were enriched for metabolic and transcriptional processes. Furthermore, WGCNA analyses identified one module of genes enriched in immune processes which was positively correlated to disease status, and a second module of genes, enriched in transcriptional and translational processes, which was negatively correlated to disease status. Together these findings not only provide insight into the immune response of E. calyculata, but also demonstrate a clear tradeoff between immune response and fitness of colonies that may have important ecological consequences.

P3.206 FULBRIGHT, MF*; PENNING, DA; HILLARD, CJ; University of Lousiana at Lafayette, Missouri Southern State University, University of Louisiana at Lafayette; *fulbrightm@louisiana.edu*

Scaling of Terrestrial and Arboreal Defensive Strikes by Ratsnakes

Until recently, only a few studies quantified striking performance in snakes. Aside from fleeing predators, snakes use defensive strikes to evade capture. Ratsnakes are semi-arboreal snakes that must dispel predators in both terrestrial and arboreal environments. We measured defensive terrestrial and arboreal strikes to determine if snakes modulate their strike performance relative to the habitat they occupy. To determine the scaling of striking performance, snakes were measured from an ontogenetic range of body sizes. We are still analyzing the effects of body size on strike performance, but in paired analyses terrestrial strikes were significantly higher in maximum velocity, strike duration, and strike distance than perched strikes ($p < 0.01$ for all). Performance of snakes in arboreal habitats is likely confounded by the need to use a portion of the posterior part of the body to maintain contact with limbs and prevent falling.

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Physiological effects of changing urbanization on eastern painted turtle populations

Continuously expanding human populations place extensive demands on society, with the needed homes and resource extraction operations causing a steady increase in the proportion of land either directly or indirectly impacted by humans. These anthropogenic effects do not limit themselves to terrestrial organisms. Industrial pollution, vehicles, and recreational activities often impact aquatic ecosystems in the vicinity of human development. Using painted turtles (*C. picta picta*) as a model organism, we seek to examine the effects of transitioning from a relatively rural environment to a heavily-impacted environment on physiological mediators such as the stress response and the immune system. We sampled and marked turtles at three locations in eastern Massachusetts: rural ponds in a nature preserve; a pond adjacent to a housing complex and a university; and previously rural ponds next to an ongoing housing development. Via analysis of corticosterone levels in blood and claw samples and of blood markers for health and immune function, we hope to track the physiological effects of the housing development on the turtles over several years. We present here preliminary results from the first season of research, including potential indicators of depressed immune function at the currently-urbanizing site, low calcium levels in both urban and urbanizing sites, and low or undetectable baseline corticosterone levels in all tested animals. We also note that all sites were afflicted by severe drought during the bulk of the sampling period, with substantial shrinkage of available habitat volumes.

42.6 GABLER, MK*; GAY, DM; WESTGATE, AJ; KOOPMAN, HN; Univ. of North Carolina, Wilmington; *mkg5178@uncw.edu*

Microvascularity and nitrogen solubility of the adipose tissue of diving tetrapods

Diving marine tetrapods experience physical variation in their environments (i.e. decreased temperature and increased pressure), which introduces significant physiological challenges. Adipose tissue is of particular concern for diving physiology, because N_2 gas is 5 times more soluble in fat than water/blood. Therefore, at any blood/tissue interface, gas will diffuse from blood into tissue, potentially increasing the risk of decompression sickness. Exposure of tissues to N_2 gas is a function of pressure, N_2 solubility, blood flow, and the number of blood vessels. Interestingly, the microvascularity (e.g. capillaries, microarterioles and microvenules) and the N_2 solubility of the adipose tissue of diving tetrapods have never been examined. Percent microvascularity was determined by incubating frozen sections from terrestrial mammals (*Sus scrofa*, *Ovis aries*, *Capra aegagrus hircus*, *Bos taurus*) and diving tetrapods (*Hippopotamus amphibius*, *Dermochelys coriacea*, *Caretta caretta*, *Somateria mollissima*, *Phygoscelis adeliae*, *Balaenoptera acutorostrata, Balaenoptera borealis*) in a solution of NBT/BCIP to stain for endogenous alkaline phosphatase. Nitrogen saturation (as measured by our previously described apparatus) does not differ across taxa. In contrast, there is considerable variation in microvascular density across species. Percent vascularity ranges from 0.81 to 5.40% in terrestrial mammals and 2.03 to 8.12% in diving tetrapods, indicating the potential for gas exchange. Preliminary analysis suggests that the fatty acid profiles and fatty acid chain lengths may further help to distinguish which taxa may be more at risk of decompression sickness.

54.5 GAFFNEY, AM*; MCCORMICK, JJ; MERMIER, CM; WITT, CC; Univ. of New Mexico; *arielgaffney@gmail.com*
Elevational replacement hummingbird species exhibit differing physiological responses to experimental hypobaria.
The role of hypoxia tolerance in limiting species elevational distributions is poorly understood. Species distributions are predicted to shift upslope with warming, causing exposure to hypobaric hypoxia. Hummingbirds exhibit exceptional O2 consumption rates which make them particularly susceptible to changes in PO2. The lowland Black-chinned Hummingbird and montane Broad-tailed Hummingbird are elevational replacement species that compete for nectar resources at mid-elevations where they overlap. We have previously shown, using a hypobaric chamber that these two species differ in their behavioral response to low pressure. Competitive dominance shifts from the lowland to montane species under reduced pressure conditions. We captured adult males of both species from the zone of overlap to test the effects of reduced pressure on the physiological response. Specifically, we asked does the hematological response to low pressure differ between high and low elevation species. To quantify the hematological response to hypobaric hypoxia, we acclimatized birds of each species at either the pressure equivalent of 1600 m or 4600 m and then collected blood samples. We measured total hemoglobin concentrations, haematocrit and mean cell volume of red blood cells. Black-chinned Hummingbirds show a decrease in the mean cell volume in response to low pressure that Broad-tailed Hummingbirds do not. The hematological response to hypobaric hypoxia seen in low elevation species, but not in high elevation species, mimics the observed behavioral response. This suggests that differential adaptation to atmospheric pressure contributes to the maintenance of stable elevational replacement distributions in hummingbirds.

17.1 GAGLIARDI, S. F.*; COMBES, S.A.; Univ. of California, Davis; *gagliardi@ucdavis.edu*
The High Cost of Flapping Faster: Metabolic and Kinematic Changes in Heavily Loaded Bumblebees
Bumblebees spend much of their time collecting and carrying large loads of resources to bring back to the hive. Flight is energetically costly and carrying massive loads presumably adds to this cost. We examined the effects of loading in 30 worker bees by adding artificial loads equivalent to 40% of their fed mass (body mass plus nectar load). We measured carbon dioxide production, wing beat frequency, and stroke amplitude in each bee while carrying nectar only (lightly loaded), or nectar plus an artificial load (heavily loaded), randomizing the order of treatments. We expected that carbon dioxide production would increase linearly with added load, and that this would be correlated with an increase in wing beat frequency and/or stroke amplitude. While carbon dioxide production was consistently higher in heavily vs. lightly loaded trials, the increase in metabolic rate was not strongly related to the change in load. Stroke amplitude was strongly correlated with the percent loading ($R^2 = 0.73$), but flapping frequency showed no significant relationship with loading. Rather, flapping frequency was strongly influenced by trial order, with bees tending to lower their flapping frequency during the second trial, whether lightly or heavily loaded. The change in metabolic rate between trials was strongly related to the change in flapping frequency ($R^2 = 0.52$) but unrelated to the change in stroke amplitude ($R^2 = 0.03$). Overall, while estimated forces produced by the flapping wings increased consistently with the total load, contributions to force from frequency and amplitude varied between individuals, with resulting differences in the energetic cost of load carriage. This suggests that bees can accommodate large, additional loads during flight while tailoring their wing kinematics to their energetic state.

P3.132 GAILLARD, E*; KOVACS, J; Spelman College; *egaillar@scmail.spelman.edu*
Effects of Urbanization on Bird Biodiversity in Florida
As the world continues to move towards operating on a global scale and countries become increasingly modernized and industrialized, how land is used is rapidly changing. Modernization and industrialization are often accompanied by urbanization and building on previously undeveloped land. Biodiversity is essential to the maintenance of local ecosystems, and urbanization can have dramatic effects on the abundance and types of biota that live in an area. Changes in local ecosystems can result in alterations in the population densities of animal and plant species by affecting resource availability, including the availability of food and shelter. We are interested in determining the effect that urbanization has on bird biodiversity over time. Using publicly available data collected by the citizen science program eBird, we have calculated bird biodiversity measurements for multiple locations in Florida spanning a 10 year period. We then calculated changes in land use and urbanization in those same locations over the same 10 year period. We predict that areas with increased urbanization will also have a decrease in bird biodiversity.

90.4 GAITAN DAZA, L.*; SZCZEBAK, J.T.; RHYNE, A.L.; WARREN, K.S.; Roger Williams University, Rhode Island, Roger Williams University, Rhode Island; The New England Aquarium, Boston; *lgaitandaza299@g.rwu.edu*
Morphological and Temporal Characterization of the Embryonic and Larval Stages of the Yasha Goby Stonogobiops yasha
The yasha goby *Stonogobiops yasha* is a specie that has remained largely unstudied since its discovery in 1997, despite its high value in the marine ornamental trade. *S. yasha* was successfully bred in captivity for the first time in 2016 by the Marine Lab at Roger Williams University. Facilitated by this milestone, this study aimed to describe the morphology and timing of major embryonic stages, develop a staging series for the larval period, and assess age at metamorphosis. Embryology was documented using video and camera lucida sketching, and larval development was documented using microphotography to measure body length and characterize onset of key morphological changes. Time to metamorphosis was measured at onset, as well as at 50% and 100% of the population. Embryonic development lasted 6 days, with larval hatching occurring the morning of day 6. Flexion occurred between day 8-12, settlement morphology was evident at day 15-20, and metamorphosis took place at day 27- 50. Food availability appeared to affect the duration of the larval period, as well as the overall survival of individuals. These results are the first characterization of the early life history of this genus, and reveal broader implications for the role of culture environment on larval growth, metamorphosis, and survival.

43.6 GALASKA, M.P.*; MAHON, A.R.; SANTOS, S.R; HALANYCH, K.M.; Auburn University, Central Michigan University; *mpg0009@auburn.edu*

Crossing the divide: Impact of an open ocean barrier on brittle star (Astrotoma agassizii) phylogeography.

Astrotoma agassizii is a brittle star known to occur in both the Southern Ocean and the waters surrounding southern South America. Although described as a brooder from South America, lecithotrophic larvae have been recovered in the Southern Ocean. In this study, genetic connectivity between the Southern Ocean and South America is investigated along with phylogeography within each region. These genetic analyses were performed using a nuclear Single Nucleotide Polymorphism (SNP) based approach, 2b-RAD, in addition to mtDNA markers, COII and 16S. Sampling includes individuals from the Argentinian waters of South America and a geographic range from the Ross Sea spanning through the western Weddell Sea (> 5,000 km) for the Southern Ocean. Analyses revealed that the Antarctic Polar Front serves as an imperfect barrier to dispersal. Although phylogeographic patterns reveal structure, unique South American haplotypes are recovered by the Antarctic Peninsula.

P1.220 GALLOWAY, K/A*; GRUBICH, J/R; PORTER, M/E; Florida Atlantic University, Boca Raton, FL, The Field Museum of Natural History, Chicago, IL; *kgalloway2016@fau.edu*

To bend a lionfish spine: Mechanical properties of fin spines of Pterois volitans

While venomous spines are used for defense in many ray-finned fishes, the red lionfish, *Pterois volitans*, is unique in that it has a diverse array of spines (13 dorsal, 2 pelvic, 3 anal). We suspect that spines located in different fins may vary in mechanical properties, dependent upon spine function (i.e. defense or locomotion,). *Pterois volitans* may not require all 18 venomous spines for successful defense against natural predators in the Indo-Pacific and Red Sea. They have been shown to be successful ambush hunters that confuse prey with their large fan-like pectoral fin rays. We quantified the relationship between the unique cross-sectional geometry of lionfish spines to their associated bending and compressive properties. We performed two point cantilever testing of each spine to determine the force required to break the spine and location of the break. Young's modulus, second moment of area, and flexural stiffness were analyzed after cross-sectional area was determined at the point load. Mechanical properties of the extraordinary spine morphology of lionfish can be informative for examining evolutionary tradeoffs between protection and hydrodynamic function of fins. These tradeoffs can provide insights into how lionfish are such successful invasive species despite the apparently reduced locomotory performance.

P3.108 GAMBOA, D.A.*; WORKING, C.L.; SMITH, J.E.; Biology Department, Mills College, Oakland, California 94613; *jesmith@mills.edu*

Spatial and temporal network dynamics of free-living California ground squirrels

Although social structures vary spatially and temporally, traditional sampling approaches are often unable to fully capture this heterogeneity. In this study, we integrate recent technological advances in network theory and automated data loggers to reveal the dynamics of spatial associations in free-living California ground squirrels (*Otospermophilus beecheyi*). *O. beecheyi* are facultatively social rodents that forage above ground, but rest and seek refuge from predators in below-ground burrow systems. As part of a long-term study, we regularly live trapped and released *O. beecheyi* at our field site in northern California. Upon first capture of each individual, we inserted a Passive Integrated Transponder (PIT) tag beneath its skin. This tag provides a reliable lifetime 'barcode' for permanent identification. Here we deployed automated sensors to monitor each time a squirrel passed through a burrow entrance. Specifically, PIT tag readers (antenna loops) were placed inside of each burrow entrance. Data loggers were deployed at two distinct locations at the study site and recorded movements continuously for almost a year. Readers logged movements of individual squirrels (as presence-absence events) at a temporal resolution of one minute. Social network analysis of these data revealed that spatial associations vary across multiple temporal scales (e.g., hour to hour, day to day, month to month). Our results therefore uncover short and long-term dynamics of spatial associations within these free-living mammals. These data have important implications for understanding disease, parasite and information transmission across spatially and temporally dynamic networks.

116.1 GAMBOA, MP*; SILLETT, TS; FUNK, WC; GHALAMBOR, CK; Colorado State Univ, Migratory Bird Center, Smithsonian Institution; *mgamboa@rams.colostate.edu*

The role of selection and gene flow in shaping thermal tolerance of song sparrow populations exposed to a climatic gradient

Natural selection across environmental gradients can lead to locally-adapted phenotypes, but the homogenizing effects of gene flow may mediate this outcome. Island populations are ideal for studying the interaction of divergent selection pressures and gene flow on phenotypic variation as water barriers presumably pose a barrier to dispersal. However, the enhanced dispersal ability of birds may increase gene flow among islands and potentially constrain selection. To infer the relative role of gene flow and selection in shaping phenotypic variation, we assess the degree to which song sparrow (Melospiza melodia graminea) populations distributed along a distinct climate gradient on the Northern California Channel Islands are locally adapted given varying degrees of isolation. We used landscape genomic analyses of SNPs to infer gene flow and population structure across islands. We coupled this with analyses of phenotypic variation in morphological and physiological traits related to thermoregulation. Despite the relatively short distances between the islands, our population genomic data revealed limited gene flow between islands. We found song sparrows have larger bills on hotter islands; a pattern previously suggested to facilitate increased heat dissipation. Flow-through respirometry experiments reveal higher upper critical temperatures of the thermoneutral zone on hotter islands. However, we found no difference in basal metabolic rate (BMR) despite our prediction that birds on hotter islands would have reduced BMR. Collectively these results suggest populations can diverge in morphological and physiological traits, even in the presence of some gene flow.

P1.235 GAMEL, K*; FLAMMANG, BE; New Jersey Institute of Technology; *kmg27@njit.edu*
Bioinspired, long-term, reversible adhesion
Manmade adhesives often fail on wet, compliant surfaces, which can result in poor performance and loss when attaching sensors in medical, defense, and research situations. However, a number of fishes have evolved adhesive discs that allow them to adhere under challenging wetted conditions. In particular, the remora fishes have the ability to attach to wet, compliant bodies under high shear conditions for extended periods of time. This research addresses the lack of underwater adhesives by using remora attachment as a bioinspired model. The goal of this work was to produce an adhesive platform suitable for attachment of instruments for biologging and telemetry research under challenging conditions. Using computed microtomography (microCT) scans of hard and soft tissues of the remora disc as a starting point, we developed a 3D-printed model for experimental testing. Ongoing testing has informed the lowest functional module of this hierarchical system is that will produce adhesion to both smooth-compliant and rough surfaces, under a range of flow speeds.

P3.71 GANDLER, HI*; STANHOPE, ME; SHEA, DN; PASCUAL, MG; YU, A; LAMEYER, TJ; RONCALLI, V; CIESLAK, MC; CHRISTIE, AE; DICKINSON, PS; Bowdoin College, Univ. of Hawaii at Manoa; *hgandler@bowdoin.edu*
Intrinsic peptidergic modulation in the lobster cardiac neuromuscular system: A transcriptomic analysis of peptides and peptide receptors in cardiac ganglion and muscle
Central pattern generator (CPG)-effector systems can produce flexible rhythmic motor output via modulation by both intrinsically- and extrinsically-derived neuropeptides. The cardiac neuromuscular system in the lobster, *Homarus americanus*, which controls the movement of the heart musculature, is a well-studied but simple CPG-effector system that has been used extensively for investigating peptidergic control of rhythmic behavior. Here, transcriptomes were generated for the two components that comprise the cardiac neuromuscular system, the cardiac ganglion (CG) and cardiac muscle (CM). Transcripts encoding precursor proteins for approximately ten peptide families, including diuretic hormone 31, diuretic hormone 44, myosuppressin, and proctolin, were identified from the CG transcriptome, suggesting that these peptide groups may be produced by neurons in the CG. Transcripts encoding receptors for many of the peptides identified from the CG, including those for all four of the above-mentioned peptide families, were also identified from the CG and/or CM transcriptomes, suggesting that these peptides serve as intrinsic modulators of the cardiac neuromuscular system. Supported by: NSF (IOS-1353023, IOS-1354567, OCE-1459235), NIH (8P20GM103423-12), Cades Fdn., University of Hawaii at Manoa's Undergrad Res. Opp. Prog., APS Undergrad Res. Fellowship, Doherty Fdn./Bowdoin College

61.4 GANGLOFF, EJ*; SPARKMAN, AM; BRONIKOWSKI, AM; Iowa State Univ., Westmont College; *gangloff@iastate.edu*
Individual Heterogeneity in Behaviour and Physiology Affects Fitness in the Garter Snake Thamnophis elegans
Accumulating evidence suggests that behavioural and physiological performance can covary within individuals. Additionally, the strength of this correlation can vary among individuals, and there may be fitness consequences of such individual heterogeneity. These patterns of covariation, inter-individual differences, and fitness consequences have been largely unstudied in ectothermic amniotes despite that reptiles have both behavioural lability and extreme physiological flexibility. We test the fitness consequences of complex phenotypes by combining measures of hormonal function, behaviour in two contexts, and reproductive success in females of the garter snake *Thamnophis elegans*. We find that these snakes are consistent over time in behavioral traits, but not physiological traits. Furthermore, these traits interact to affect the birth condition of their offspring, which subsequently bears enormous influence on growth and survivorship. Those moms fitting a "low reactivity" profile - characterized by reduced levels of stress hormone (corticosterone) and available energy stores (glucose), slower escape behavior, and reduced information-gathering via tongue flicking - gave birth to offspring in better body condition that, in turn, grew faster and lived longer under captive conditions. This study provides empirical support to connect axes of individual variation with fitness and furthermore proposes a mechanism for how such individual differences may be maintained within populations.

79.1 GARCIA, MJ*; HUNTER, KL; TAYLOR, RC; University of Kentucky, Salisbury University; *mjgarcia@salisbury.edu*
Dueling Frogs: Male Assessment of Competitor's Call Frequency During Agonistic Bouts
During the breeding season male green treefrogs (*Hyla cinerea*) congregate in leks and produce auditory signals, "calls", for the principal purpose of attracting females. A critical component of a male call is it's frequency; with low frequency calls being more desirable to potential mates relative to high frequency calls. Due to limited space within a tightly packed lek, males frequently participate in aggressive, dueling bouts with other males and utilize the above mentioned calls to deter their competitors. In this study we sought to examine whether males assess the call frequency of a competitor male and alter their aggressive decisions (i.e. engage, persist, or retreat) based upon their opponents call frequency. We hypothesize that low frequency calls, which are more desirable to females and indicative of a competitively superior male, would elicit reduced aggression from focal males. Over the 2015 and 2016 breeding season we collected amplexed (male-female) pairs at a local population in Maryland. Pairs were separated and the males were placed in sound proof chambers where they were exposed to playbacks of male calls of varying frequencies (high, average, and low). Latency to first call, time spent calling, number of calling bouts, and frequency of the focal male's call were recorded. Preliminary analyses indicate that males have higher latency to first call and spend less total time calling when faced with low frequency male calls. A full analysis of our results is currently underway with the goal of revealing whether and how males assess and utilize competitor call frequencies in their aggressive decisions.

10.7 GARCIA, S.M.*; KOPUCHIAN, C.; FUXJAGER, M.J.; RIEDE, T.; GOLLER, F.; University of Utah, CECOAL-CONICET, Wakeforest University, Midwestern University; *Sarah.Garcia@utah.edu*

Evolution of diverse song: functional morphology of the avian syrinx and motor control in suboscines and oscines.

The avian vocal organ, the syrinx, gives rise to highly diverse vocal behavior. While gross anatomy and syringeal muscles of the syrinx have been studied for centuries, relatively little is known of how syringeal morphology relates to function. Histological composition of the labia, the sound producing structures of the syrinx, plays an integral role in phonation. In addition to their size and muscular control, the composition and orientation of elastic proteins of the extracellular matrix significantly impacts acoustic features of the generated sound. Current histological data describing oscine syringes indicate a positive and nonlinear correlation between spectral range and histological complexity of the labia. Here we present data on the diversity of syringeal histological composition within suboscine families (22 species representing 5 families), and compare this diversity to that found in oscines (7 species). We then relate morphological characteristics to the acoustic features in the respective vocal repertoires and test the hypothesis that vocal learning and vocal motor control is associated with morphological complexity, which we assessed through tracheosyringeal nerve cuts. The range of acoustic features of specific vocal repertoires is bounded by morphological features, and characteristic acoustic features can arise from morphological specializations. Motor control enables regulation of spectral and other acoustic features within the morphologically determined boundaries.

P2.190 GARDNER, S*; CLINE, G; MWEBI, N; RAYBURN, J; Auburn University, Jacksonville State University; *stg0015@tigermail.auburn.edu*

Developmental effects and DNA damage in spotted salamander, Ambystoma maculatum , larvae from exposure to of arsenic and chromium

Amphibian populations have been declining, with possible contributions being anthropogenic activities that may elevate concentrations of environmental contaminants such as metals. As amphibians play vital roles in transferring nutrients and energy from aquatic to terrestrial environments, declines in populations have the potential to impact ecosystems. Using *Ambystoma maculatum*, a common mole salamander throughout the eastern part of the United States, to monitor effects from exposure to arsenic and chromium may be advantageous as these salamanders breed in vernal pools that may be contaminated. In the current study, larvae exposed to arsenic and chromium showed increasing mortality, malformation, and genotoxic responses from increasing exposure, while growth responses decreased with increasing exposure. Exposure to a mixture of arsenic : chromium resulted in significantly more DNA damage at lower concentrations than individual exposure to these contaminants, indicating a greater risk to developing salamander larvae in areas contaminated with both arsenic and chromium.

P2.136 GARDNER, S*; GRIDER, S; CAMPBELL, P; Oklahoma State University , Oklahoma State University; *sarah.a.gardner@okstate.edu*

Effects of Disrupted Genomic Imprinting on Maternal Behaviors in an Interspecific Mouse Cross

Genomic imprinting, the epigenetically regulated, selective silencing of either maternal or paternal alleles, is essential to embryonic growth and development in mammals. To date, most experimental work on imprinted genes has focused on direct effects of genomic imprinting on conceptus (the collective term for the placenta and fetus) size and embryonic development. However, imprinted genes are highly expressed in placental endocrine cells and are implicated in the induction and maintenance of maternal care. Disruption of genomic imprinting is relatively common in mammalian hybrids: parent-of-origin dependent effects on embryonic growth and development are documented in several rodent genera. We are exploring the effects of placental loss of imprinting on the physiology and maternal behavior of otherwise normal females, using a cross between two closely related species of mice (*Mus musculus domesticus* and *M. spretus*). Genomic imprinting is partially disrupted in hybrid conceptuses in this cross; how this may affect maternal behavior and mother-pup interactions is unknown. Pup retrieval, milk letdown and suckling were assayed in the mothers of hybrid and non-hybrid litters, and maternal observations taken over the first nine days post-partum were scored for time in and out of the nest. Pup ultrasonic vocalizations - signals that influence maternal responsiveness - were quantified on days three, six and nine post-partum. As the first test for effects of loss of placental imprinting in a natural system, the results of this experiment will advance understanding of the role of placental imprinted genes in regulating the onset of maternal care and facilitating mother-offspring interactions.

S2.7 GARLAND, JR., T.*; ALBUQUERQUE, R.L.; Univ. of California, Riverside; *tgarland@ucr.edu*

Locomotion, energetics, performance, and behavior: a mammalian perspective on lizards, and vice versa

Animals are constrained by their abilities and by interactions with various environmental factors. Constraints range from physical impossibilities to energetic inefficiencies, and may entail trade-offs. Considering locomotion and activity metabolism, allometric comparisons of mammals and lizards (as representative terrestrial vertebrate endotherms and ectotherms) can illustrate those perspectives because the two groups differ greatly in metabolic capacities, energetic costs, and thermoregulatory patterns. Such allometric comparisons are useful and unavoidable, but comparisons of "outliers" (species unusual for their clade) can inform evolutionary scenarios, as they help to indicate extremes of possible adaptation within mammalian and saurian levels of organization (grades). We compare mammals and lizards for standard metabolic rate (SMR) at 35-40 C, maximal oxygen consumption during forced exercise (VO_2max), net (incremental) cost of locomotion, maximal aerobic speed (MAS), maximal sprint speed, daily movement distance, daily energy expenditure (DEE) during the active season, and the ecological cost of transport (ECT = % of DEE attributable to locomotion: Garland 1983 Am. Nat. 121:571-587). On average, MAS is ~8-fold higher in mammals, while SMR and VO_2max are ~6-fold greater, but overlap can occur. Maximal sprint speeds are similar for smaller mammals and lizards. On average for both lineages, the ECT is surprisingly low, somewhat higher for lizards, and positively allometric. Ecological-energetic constraints related to locomotion are most likely in large, carnivorous lizards. Overall, these comparisons suggest that the evolution of mammalian endothermy did not require major changes in locomotor energetics, performance or associated behaviors.

S11.4 GARM, A*; PETIE, R; BEER, S; WENTZEL, C; HALL, M; Uni. of Copenhagen, Denmark, Australian Institute of Marine Sciences; *algarm@bio.ku.dk*

Eyes and vision in starfish

For a long time starfish were thought to be mainly guided by olfaction when navigating their habitat. Still, except for the borrowing species all examined species has a prominent eye at the tip of each arm situated at the base of the distalmost tube foot. They are compound eyes with bright red screening pigment but they lack proper focusing optics. Depending on species and size of the animal there are between 10 and 300 ommatidia in each eyes. All examined eyes have a single opsin with peak absorbance in the deep blue part of the spectrum and in accordance with their slow movements we also find that they have the lowest temporal resolution of any eye examined to date with flicker fusion frequencies of less than 1 Hz. We have shown that for the coral reef inhabiting Blue starfish (Linckia laevigata) and the Crown of thorns starfish (Acanthaster planci) these eyes are necessary and sufficient for homing in on the coral reef. This behaviour utilizes proper image formation with a spatial resolution in the order of 10-15 degrees. The arm tip of A. planci ends in a movable knob holding the terminal tube foot, which allows for actively adjusting the vertical part of the visual field. This is used to stabilize the visual field when the arm bends and possibly to enhance the contrast of horizontal lines through a scanning movement. Despite their many protective spines A. planci has a number of predators including butterfly fish (Chaetodontidae) and light reception is also supporting a protecting behaviour where the exposed distalmost tube feet are withdrawn if a shadow passes. This turns out to be at least partly controlled by extraocular dermal photoreceptors, though, since blinded animals still perform the behaviour.

100.6 GARNER, AM*; SIMAN, KE; WRIGHT, A; NIEWIAROWSKI, PH; The University of Akron, Program in Integrated Bioscience , The University of Akron, Program in Integrated Bioscience; *amg149@zips.uakron.edu*

What Goes Up, Must Come Down: The Effect of Running Orientation on the Speed of Adhesive Locomotion in Geckos

Over the past few decades, the number of studies investigating the gecko adhesive system has rapidly increased, particularly after it was discovered that van der Waals forces were the major source of gecko adhesion. Although numerous gecko-inspired synthetic adhesives have been fabricated and implemented into gecko-inspired robots, much is still unknown about how geckos navigate their environment using dynamic adhesive locomotion, thus perhaps limiting the effectiveness of such designs. Most studies investigate gecko adhesive locomotion while geckos are traveling upwards on vertical or inclined substrates. Given the directionality of the gecko adhesive system, traveling downward on a vertical substrate should be more difficult. To test this, we measured the average and maximum sprint velocity of two gecko species while they were sprinting upward or downward on a 2 m vertical acrylic racetrack. Preliminary data suggests that running orientation by itself had no significant effect on the average or maximum sprint velocity of the geckos, however, sensitivity to orientation was different for the two species tested (significant species by orientation interaction) for mean, but not maximum velocity. Further studies of gecko locomotion under the broad range of conditions they experience in the field is likely to influence the design of gecko-inspired synthetic adhesives and provide greater understanding as to how geckos navigate difficult terrain.

98.1 GART, SW*; LI, C; Johns Hopkins Univeristy; *swgart@jhu.edu*

Dynamic traversal of large gaps and high bumps by cockroaches

To survive, terrestrial insects must traverse obstacles like rocks, litter, vines, and exposed roots comparable in size to or even larger than themselves. Much has been known about how insects slowly negotiate obstacles and how lizards and birds run over small obstacles (up to half hip height). However, it is less clear how well insects can dynamically traverse large obstacles comparable to their size. Here, we challenged the discoid cockroach (*Blaberus discoidalis*) to run into two types of large obstacles, a gap ($N = 7$ animals, $n = 350$ trials) and a bump ($N = 6$, $n = 270$), and varied gap width from 0.2 to 1 body length (*BL*) and bump height from 1 to 4 hip height (*H*). The animal was able to dynamically traverse gaps as large as 1*BL* and bumps as high as 2*H*. For the gap, the probability of dynamic traversal (not falling into and then climbing out of the gap) decreased from 100 ± 0 % to 5 ± 1 % as gap width increased from 0.2*BL* to 1*BL* ($P < 0.0001$, repeated-measures ANOVA). Dynamic modeling well predicted observations of gap traversal, and demonstrated that the animal behaved like a forward-moving rigid body falling on one end and used its head to bridge large gaps. For the bump, probability of dynamic traversal (average forward speed does not fall below minimal running speed) decreased from 87 ± 2 % to 33 ± 4 % as bump height increased from *H* to 2*H* ($P < 0.0001$). The animal climbed over higher bumps (3*H* and 4*H*) at slower exploratory speeds. For both gaps and bumps, running at a higher speed (higher kinetic energy) and with a more erect posture (higher potential energy and larger body pitch) facilitated dynamic traversal. Our study provides inspirations for robots to use kinetic energy to dynamically traverse large gaps and high bumps common in terrains like landslides and building rubble, a scenario challenging for slow navigation using sensing and path-planning.

P3.103 GASKIN, AG*; COLLIN, R; University of Idaho, Moscow, Smithsonian Tropical Research Institute; *gask5472@vandals.uidaho.edu*

Slime Trail Tracking in Nerita scabricosta

Mucous trail following is a strategy used by a variety of snails and may be utilized for mating, foraging, and ease of locomotion. *Nerita scabricosta*, an abundant intertidal snail in the Bay of Panama has been occasionally observed to trail follow in the field. We tested the hypotheses that (1) snails do follow the trails of other snails and (2) that following behavior is sex specific, with male snails tracking females more often than other males. For trail following assays, snails were placed in the middle of a circle on an acetate sheet, which was covered in a fine mist of water. We recorded the time it took the snail to leave the circle, the 30 degree interval in which it left, and the total distance the snail traveled. After the first, or marker snail, made its trail, the acetate sheet was rotated, and a second, or tracker snail, was introduced in the center of the circle and its route was documented in the same way. For the tracker snail we recorded the amount its trail overlapped the marker's trail. Snails followed each other more often than would be expected by chance, but sex was not a significant factor. Snails of one sex were no more likely to follow snails of the other and neither sex showed a greater propensity to follow than the other. We conclude that the *Nerita scabricosta* does not use snail tracking as a means of finding a mate, as do Littorinid snails, and that trail tracking may be more important in searching for food, saving energy and mucous during travel, or in homing behaviors.

89.3 GAUBERG, J*; KELLY, SP; York Univ., Canada;
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Effect of ion-poor water on region-specific paracellular permeability properties of rainbow trout skin

Skin is the main component of the vertebrate integumentary system and its primary function is to act as a protective barrier. Due to its crucial role as a barrier tissue, the basic structure of vertebrate skin (e.g. epidermis, dermis) can be observed across species. By separating internal and external environments, skin can help to prevent pathogen invasion, regulate body temperature, and maintain electrolyte and fluid balance. Teleost fishes do not possess heavily keratinized outer layers of skin. Instead, the skin of these fishes presents an outer layer of living epithelial cells that are in direct contact with the water and must deal directly with the challenges of life in an aquatic setting. For example, in freshwater (FW), teleosts possess hyperosmotic internal fluids, which leads to passive ion loss across tissues that interface with the surroundings. Yet despite a complex structure and extensive contact with the external environment, the skin of adult FW fishes is classically regarded as a static, passive barrier to diffusional ion loss. Recent studies have shown that select tight junction (TJ) proteins alter in transcript abundance during salinity acclimation, but a broader picture of how the molecular components of the fish skin TJ complex respond to environmental change is lacking. The present study examined regional TJ protein response to environmental change (i.e. acclimation to ion-poor water, IPW) in FW rainbow trout (*Oncorhynchus mykiss*) skin. Acute and chronic treatment with IPW resulted in alterations of Cldn protein abundance in a region-specific and time-dependent manner. This study also provided a new look into an ex vivo technique, the Franz Cell, for measuring ion flux and paracellular permeability of fish skin. These data provide a unique look at the region-specific changes of TJ complex components in the adult fish skin and connect them to region-specific permeability properties.

P2.87 GAUDREAULT, B. N.*; DAS, S.; MYKLES, D. L.; Colorado State University, Fort Collins; *gaubrini@rams.colostate.edu*

Expression of ecdysteroid responsive nuclear receptors in limb regenerates of the decapod crab Gecarcinus lateralis

Regeneration is a phenomenon common across metazoan taxa. Decapod crustaceans including the blackback land crab, *Gecarcinus lateralis*, regenerate lost limbs in tandem with their molt cycle. Circulating steroid hormones or ecdysteroids regulate this process. The initial differentiation and proliferation of the blastema occurs during intermolt, when ecdysteroid titers are low. The resulting differentiated limb bud undergoes hypertrophic growth during premolt, as ecdysteroid titers rise and the animal prepares to molt. We hypothesize that ecdysteroid responsive genes mediate the differentiation and growth of limb regenerates. The mRNA levels of ecdysteroid receptor (*EcR/RXR*), *E75*, and *HR3* at eight limb regenerate stages (four basal differentiation and four proecdysial growth) were quantified by qPCR. All four genes were significantly upregulated during the basal phase (4 and 15 days post-autotomy). During this time the average ecdysteroid titers remained low (9.4 ± 0.4 pg/µl on day 4 and 8.3 ± 0.6 pg/µl on day 15). Interestingly, only *HR3* and *E75* were significantly upregulated in the late proecdysial stages when the animals were preparing to molt. The ecdysteriod titers at this stage peaked at 73.4 ± 10.2 pg/µl. Future work will quantify the expression of four additional ecdysteroid responsive genes (*E74*, *HR4*, *BR-C*, and *FTZ-F1*) during differentiation and growth phases and determine the effects of the suspension of limb bud growth by limb bud autotomy on the expression of all eight genes. Supported by NSF (IOS-1257732).

88.3 GAWNE, R*; NIJHOUT, HF; Duke University;
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Phenotypic variation and aposematic signaling in an arctiid moth (Utetheisa ornatrix)

The bella moth *Utetheisa ornatrix* (Lepidoptera:Arctiidae) sequesters pyrrolizidine alkaloids from host plants during its larval stage. Adults are diurnal, and previous studies have suggested that they visually signal their distastefulness to predators by means of conspicuous coloration. However, the wing patterns that give rise to this aposematic signal are exceptionally diverse within the species and remain understudied. Both the background color, and specific pattern elements of the dorsal surface of forewings vary enormously within local populations, ranging from brilliant high-contrast red, black and white, to an almost pure overall white. Using animals from a laboratory colony, we documented and quantified the range of variation in *U. ornatrix* wing patterns using spectrophotometry, and techniques from geometric morphometrics. To identify the genetic correlates of color pattern variation, we conducted a series of selective breeding experiments. In addition, the environmental contributions to wing patterns were studied by varying the conditions under which animals develop. Given that aposematic signals tend to be more effective when animals converge on a common phenotype, the fact that there is so much variation in *U. ornatrix* wing patterns is puzzling. We conclude by developing an evolutionary hypothesis which suggests that this kind of pattern polymorphism can be advantageous to aposematic organisms when dishonest signaling is possible.

P2.47 GE, ZY*; SCHWARTZ, TS; HILL, GE; Auburn University;
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Exploring the Genetic Basis of red feather pigmentation in house finch (Haemorhous mexicanus)

Carotenoid pigmentation of many bird species plays an important role in sexual selection. To produce red pigments, birds ingest yellow dietary carotenoids and convert them into red ketocarotenoids via an oxidation reaction controlled by a previously unknown ketolase enzyme. Recent work done on canary and zebrafinch have discovered a candidate ketolase gene, CYP2J19, which showed differential expression between domestic breeds with or without red coloration. We investigated the role of CYP2J19 in a wild songbird, the house finch (*Haemorhous mexicanus*), in which only males display intensive red carotenoid feather pigmentation. We successfully sequenced the CYP2J19 in house finch and compared the expression of CYP2J19 across tissues and sex during molting season. Our work provides novel insights into on the potential role of CYP2J19 in controlling production of red pigments and hence the expression of ornamental feather pigmentation in house finches.

P1.64 GEARY, B.*; WALTER, S.T.; LEBERG, P. L.; KARUBIAN, J.; Tulane University, University of Louisiana at Lafayette; *bgeary@tulane.edu*

Individual Behavioral Plasticity by Seabirds in a Disturbed Foraging Environment

Modern developments in animal tracking technology have enabled unprecedented insights into individual-level behaviors, the proximate drivers of their movements, and the ultimate consequences of movement strategies. Seabirds have maintained consistent popularity as subjects of these studies, as they can accommodate the most current developments in bio-logging devices and often serve as valuable monitors of ecosystem health. In the northern Gulf of Mexico, brown pelicans (Pelecanus occidentalis) navigate a foraging landscape that is patchy and dynamic at a variety of scales due to both natural and anthropogenic stressors. The species is therefore an ideal subject through which the trophic dynamics of the Gulf, as well as the broader significance of behavioral plasticity in uncertain environments, can be understood. From 2012-present, we have attached GPS transmitters and accelerometers to breeding adult pelicans on Louisiana barrier island colonies and simultaneously monitored nesting success throughout the summers. Consistent variation within and among individuals has been shown across several foraging metrics, including their spatial use of the foraging environment, with possible linkages to prey availability and the presence of the Gulf hypoxic zone. Further work will combine these findings with accelerometer analysis, simulation modeling, and ecotoxicological assays to understand the relative contributions of individual foraging strategies, density-dependent resource distributions, and contaminant exposure to fitness in heavily disturbed systems. Results will also be used to model population-level processes and provide unprecedented insights into the movement ecology and demography of an important Gulf seabird.

P1.127 GEDULDIG, JE*; LITWA, HP; TRICOLA, GM; PAITZ, RT; HAUSSMANN, MF; Bucknell Univ., Illinois State Univ.; *jeg039@bucknell.edu*

Individual variation in acute stress responses affects oxidative stress levels in Japanese quail (Coturnix japonica)

Vertebrates respond to stress by activating a suite of integrated physiological response mechanisms, of which a key component is the hypothalamic-pituitary-adrenal (HPA) axis. When activated, this stress response results in the release of glucocorticoids (GCs), causing an increase from baseline levels to stress-induced levels. As homeostasis is restored, GCs decrease toward baseline, and this is referred to as recovering levels. There is considerable individual variation in these three components of a stress response, and because GCs have extensive and variable effects on physiology, this individual variation can correlate with fitness. One potential consequence of a stress response is that exposure to GCs can increase oxidative stress levels. We used Japanese quail (*Coturnix japonica*) to explore how variation in an individual's stress response affects oxidative stress. Specifically, we determined how baseline, stress-induced, and recovering levels of GCs associate with baseline measures of oxidative stress (total antioxidant capacity, TAC; reactive oxygen metabolites, ROMs). We found that baseline and recovering GC levels both positively correlated to ROMs, while stress-induced GC levels did not associate with ROMs. No measure of GCs correlated with TAC levels. Because baseline GC levels reflect predictable energetic demands, our results suggest that individuals that expend more energy daily also have higher oxidative stress levels. In addition, those individuals that have a protracted GC recovery after an acute stress response are also prone to higher levels of oxidative stress, possibly due to prolonged exposure to high levels of GCs during an acute stress response.

P3.167 GEE, Z.G.*; SKOPEC, M.M.; SCHRAMM, K.; DEARING, M.D.; Weber State University, University of Utah; *zacharygee@mail.weber.edu*

Downregulation of Glutathione S-transferase May Play a Role in Dietary Specialization

Juniper foliage is a major component in the diet of some woodrats, even though it contains high levels of potentially toxic terpenes. In order to biotransform the terpenes in their diets, juniper specialists must utilize efficient metabolic pathways. Nitrogen is often a limiting factor for herbivores because plants have low levels of nitrogen and because nitrogen is lost in urine and feces. Thus it is important for herbivores to rely on biotransformation mechanisms that spare nitrogen. We analyzed liver samples from multiple populations of woodrats (genus *Neotoma*) that were either juniper specialists (*N. stephensi* and *N. lepida* from the Great Basin Desert) or not (*N. albigula*, a dietary generalist, and *N. lepida* from the Mojave Desert, a creosote specialist). This comparison allowed us to determine how strongly juniper specialists rely on the biotransformation enzyme glutathione S-transferase (GST). GST is an expensive phase II biotransformation enzyme because the conjugate contains three amino acids. We used the liver cytosolic fractions to measure variations in GST activity levels through absorption spectroscopy. While on juniper diets, both juniper specialists down-regulated their GST activity, while both non-juniper feeding species up-regulated their GST activity. The down-regulation of GST by juniper specialists likely conserves nitrogen, which is scarce in the juniper foliage. Utilizing nitrogen sparing biotransformation pathways may represent an integral step in woodrats' adaptation to diets low in nitrogen and high in terpenes.

3.5 GEHMAN, A.M.*; BYERS, J.E.; University of British Columbia, University of Georgia; *gehman@zoology.ubc.ca*

Temperature Effects on Parasite Larval Size Over Time and Across Multiple Life Stages

Temperature has predictable effects on many biological processes, and yet the effects of temperature on parasites are less well understood compared to that of free-living animals. Parasite reproduction could be optimized in a variety of ways, many of which are likely to be affected by temperature - from increased propagule production, to increased propagule longevity or increased development speed. We conducted lab experiments evaluating the effects of temperature on parasite larval production and development in the brooding parasitic castrator *Loxothylacus panopaei* in its mud crab host *Eurypanopeus depressus*. Parasitized (with single and double infections) and unparasitized hosts were exposed for 209 days to a range of temperatures (5 to 35&degC in increments of 5C) commonly experienced in the field. All parasitic larvae released from crabs were collected, quantified and measured. We found that parasite egg size stayed constant over time, and that temperature had a non-linear effect on parasite egg and nauplii size, with the largest eggs and nauplii around 15-20&degC. At 20&decC nauplii also increased in size over the time, and were larger in the hosts with a single infection that a double infection. Development time to the cyprid stage increased with temperature, while cyprid size increased with time, and decreased with brood size. Interestingly, egg and nauplii size were maximized around the same temperature as brood size, but cyprid size was not. As larvae are lecithotrophic, it is possible that increased size confers an increase in longevity and therefore increased transmission potential. With limited resources, larvae at temperatures above optima are developing faster but at the expense of size, number and host survival - which together could decrease transmission potential at higher temperatures.

2.2 GEMMELL, BJ*; SUTHERLAND, K; CONLEY, K; BOUQUET, J-M; THOMPSON, E; University of South Florida, University of Oregon, Sars International Centre for Marine Molecular Biology; *bgemmell@usf.edu*

Nature's Peristaltic Pump: Quantification of Flow around the Undulating Tail of Appendicularians

Appendicularians are pelagic tunicates (Phylum: Chordata, Subphylum: Tunicata) that can dominate zooplankton communities and their grazing can alter material flux in the water column. Understanding the mechanics and fluid dynamics of their feeding has important implications for predicting their impact on particle distributions in the upper ocean. We use high resolution, high speed video as well as a new method of micro-Particle Image Velocimetry (µPIV) to gain unprecedented spatial and temporal resolution of body kinematics and fluid motion during feeding. We show that Appendicularians produce a strikingly different flow pattern compared to other species that exhibit undulatory swimming. The resulting flows appear to be due to the tail acting as a peristaltic pump rather than a vortex-based pattern of fluid motion seen in other organisms. These findings provide insight into the unique feeding mechanism employed by these important grazers.

3.6 GENOVESE, C.B.*; MARKO, P.B.; LEI, W.; PATTON, A.; MORAN, A.L.; University of Hawaii at Manoa; *cgenoves@hawaii.edu*

Plasticity in thermal tolerance of early life history stages of marine invertebrate larvae

Temperature is a key factor in determining the physiology and distribution of marine species. The planktonic larvae of benthic marine species are likely to experience different thermal environments than adults and may also exhibit stage-dependent tolerance to thermal stress, but few studies have looked at thermal stress responses in larvae. We examined larval temperature acclimation and transgenerational effects on thermal performance in larvae of the tube-dwelling polychaete *Hydroides elegans*. To examine transgenerational effects, we raised offspring of four parental cohorts from settlement to reproductive maturity under two different constant temperature regimes, 20 and 25°C. Larvae from both parental temperatures were split and reared at 20 or 25°C. We measured LT_{50} of larvae from all four groups on Day 1 and Day 4 of development. To measure LT_{50}, larvae were exposed to a range of 12 temperatures between 21-40°C. We found that only some cohorts of *Hydroides elegans* exhibit larval temperature acclimation, but transgenerational effects were seen in every cohort; larvae produced by parents reared at higher temperatures had higher thermal tolerance in all four experiments. For a more powerful and nuanced view of the capacity for larval acclimation and transgenerational effects to buffer larval thermal performance, we are currently using a similar experimental design at a wider range of temperatures (20, 25, and 29°C) to investigate the temperature limits to performance and oxygen consumption in addition to LT_{50}. Results from these experiments will shed light on the physiological capacity of larvae of tropical marine species to coping with rapid environmental changes.

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Metabolic Plasticity of Juvenile Lake Sturgeon Associated with Rearing Temperature

Hatchery production and stocking are essential to the restoration of endemic lake sturgeon populations, but environmental factors can limit survival both in the hatchery and after release into the river system. This study investigated the effects of ambient temperature on the energy physiology of hatchery-reared lake sturgeon. Immediately after first feeding, juvenile fish were exposed to three temperatures (15, 18, and 21°C) for six weeks. Surprisingly, no differences in growth were observed between treatments, although sturgeon reared at 15°C exhibited significantly higher survival. Sampled fish were subsequently analyzed for whole-body triglyceride, glucose, and protein concentrations to examine any temperature-dependent differences in production of energy reserves in the early life stages. Lean muscle production was prioritized in the initial months of life at all tested temperatures, with protein concentrations accounting for the greatest proportion of body mass in fish exposed to 15°C. These results indicate that temperature is an important factor affecting the trade-off between rapid growth and nutritional condition of juvenile lake sturgeon. After 6 weeks, all remaining fish were transferred to 20°C and reared to stocking size (10.1±0.5 g). Standard metabolic rate (SMR) was determined for each treatment group via intermittent-flow respirometry at the three rearing temperatures. As expected, SMR increased with temperature in all treatment groups. However, lake sturgeon fingerlings initially reared at 18°C exhibited greater range in SMR across exposure temperatures. Thus, temperatures experienced in early life influence the physiological condition of lake sturgeon, and these impacts continue to influence physiological tolerance to temperature variation over the course of development to stocking size.

29.2 GEORGE, AB*; WRIGHT, B; WESTNEAT, MW; University of Chicago; *abgeorge@uchicago.edu*

Evolution of Median Fin Shape and Swimming Performance in Balistoid Fishes

Triggerfishes (Balistidae) and filefishes (Monacanthidae) power locomotion using their median dorsal and anal fins in a unique swimming mode termed balistiform locomotion. Balistoid fishes lie on a morphological continuum from fishes possessing median fins of low to high aspect ratio (AR) and a biomechanical continuum from fishes powering locomotion with broad oscillations to precise undulations of the median fins. Hydrodynamic theory and experimental evidence from other groups of fishes predict that fishes using fins of higher ARs for propulsion should be capable of higher critical swimming performance, a measure of endurance swimming capacity. We calculated ARs of dorsal and anal fins in balistoid fishes and performed phylogenetic ancestral state reconstructions to reveal that both high and low AR median fins evolved multiple times within Balistoidea. Additionally, filefishes tend to have lower AR median fins than triggerfishes. We predicted that critical swimming performance decreases with AR among multiple balistoid lineages and that swimming performance of filefishes decreases relative to triggerfishes. In order to investigate the performance consequences of evolutionary shifts in median fin shape, we performed critical swimming tests on morphologically and phylogenetically diverse balistoid species. Preliminary results for 11 balistoid species show that increasing median fin AR is associated with higher critical swimming performance (PGLS: $p = 0.0024$). Critical swimming speed is a key performance metric that may have influenced the evolution of balistoid median fin shape, although there may be additional performance metrics in which possessing lower AR median fins may be advantageous.

P1.128 GEORGE, EM*; ROSVALL, KA; Indiana University, Bloomington; *georgee@indiana.edu*

Ability to elevate testosterone varies with breeding stage in a competitive female songbird

Prior social competition is thought to physiologically prime animals for future confrontations. Research on this phenomenon in vertebrates has largely focused on males and circulating levels of testosterone (T). In recent years, however, it has become increasingly clear that that female-female competition is also widespread and adaptive in many species, but social modulation of T in females may not always be adaptive. To understand female responses to aggressive encounters in their social environment, it is critical to determine whether females are physiologically capable of elevating T. We addressed this question in female tree swallows (*Tachycineta bicolor*), a songbird with intense female competition for nesting sites. We injected females with gonadotropin-releasing hormone (GnRH) at multiple stages of reproduction, measured T levels in blood collected before and 30 min after injection, and compared these females to saline-treated controls. We found that females were able to elevate T in response to exogenous GnRH early in the breeding season (territory establishment through egg deposition), but not late (incubation and chick-rearing). Baseline T levels also declined over the season, corresponding to a seasonal decline in naturally occurring rates of aggression. These results suggest that social modulation of T may be possible early in the season when aggression is most prevalent, but females cannot elevate T during later stages when elevated T or aggression may interfere with maternal care. As a consequence, these patterns have key implications for understanding how selection shapes mechanisms of behavior in females.

100.5 GEORGE, MN*; CARRINGTON, E; Univ. of Washington; *mngeorge@uw.edu*

Mussels use seawater pH as a molecular trigger in the formation of byssus adhesive

In hydrodynamically turbulent marine environments, the settlement and survival of marine organisms depend on a strong attachment to the ocean floor. Marine mussels achieve this by anchoring themselves to rocks with stretchy, collagen-like threads (called byssal threads) that are tipped with a protein adhesive. Synthesized in seawater and curing over the course of days, the glue that byssal threads use is a bio-mechanical marvel that has inspired the synthesis of several novel synthetic glues due to its unique ability to adhere to a variety of conventionally challenging surfaces (e.g. glass, plastics, wood, and Teflon), all while in the presence of excess water, salts, and polar organic molecules. However, despite the adhesives notoriety, little is known about how the glue matures or "cures" in natural environments and under what seawater conditions this process is either accelerated or retarded - information that could be ecologically and economically relevant as seawater conditions change as a result of ocean acidification, seasonal trends in water chemistry, and biological activity. Here we describe laboratory experiments wherein mussels were sampled over the course of a year and made byssal attachments within the laboratory. Byssus glue then 'cured' in a range of seawater pH conditions for up to three weeks and were pulled to failure using a materials testing machine. Results from these assays provide insights into the role that seawater pH plays as a molecular trigger in protein assembly, in lieu of seasonal trends in mussel physiology that have been observed in field surveys and anecdotally by mussel aquaculture farmers.

P3.122 GEORGES, J*; LOGAN, ML; WATSON, CM; Midwestern State University, Stellenbosch University; *jeanel.georges@gmail.com*

Potential consequences of Anolis cristatellus invasion of Dominica on endemic Anolis oculatus populations in a dynamic thermal environment

Dominica is historically a one-Anole Island with *Anolis oculatus* inhabiting most available habitats. Populations of this species have undergone adaptive radiation with a number of recognized sub-populations that are morphologically distinct but not reproductively isolated. Fifteen to twenty years ago a second Anole, *Anolis cristatellus*, invaded Dominica and has sense become relatively widespread. In the warm lowlands, the two species appear to remain in sympatry with a noted constriction of the native species' niche. However, they do not co-occur in upland sites which tend to be cooler and wetter. Here we investigate the thermal ecology of both species to determine what factors may be important for their coexistence and how we may expect climate change to affect their distribution. We characterize their thermal habitats and report differences in thermal optimum for the fitness-related measures of sprint speed and bite force of both species in two habitats. These data show that they are thermally distinct yet may be partitioning their thermal niches. However, climate change may favor *A. cristatellus* if temperatures continue to increase at the current rate.

P3.216 GERALD, GW*; THOMPSON, MM; LEVINE, TD; WRINN, KM; Nebraska Wesleyan University, Carroll University, University of Wisconsin, Rock County; *ggerald@nebrwesleyan.edu*

Leg Autotomy and Surface Incline Interactively Affect Speed and Kinematics of Pholcid Spiders (Pholcus manueli)

Autotomy, self-amputation of an appendage, is a common adaptation observed in a variety of animal taxa that evolved to increase the chance of surviving a predatory encounter. Despite this benefit, there can be severe negative consequences on locomotor performance, which is crucial for avoiding predators and finding food, mates, and suitable habitat. In spiders, studies have found that leg autotomy hinders sprint speeds and prey capture abilities. However, to our knowledge, no study has examined the impact that leg autotomy has on speed and kinematics of spider locomotion on inclined substrates. Therefore, using a repeated-measures design, spiders were run on one horizontal substrate and two inclined (45° and 90°) substrates both before and after autotomy of one of the first pair of legs in the cellar spider (*Pholcus manueli*). Speed, stride length, stride cycle time, and duty factor were measured in all remaining legs. We found that speed and stride length decreased with increasing incline despite small body size. However, stride length increased following autotomy during non-vertical locomotion, likely to compensate for the missing leg. We found that autotomy and incline interact to affect stride cycle time, which was highest in autotomized spiders at 45° inclines. Duty factor increased in the first leg opposite of the one autotomized at all inclines. Pholcid spiders appear to compensate for limb loss differently on various inclines. Future studies should compare the effect of removal of different legs on performance and kinematics to get a better understanding of the negative consequences of leg autotomy in nature.

59.5 GERMAN, DP*; HERAS, J; Univ. of California, Irvine; *dgerman@uci.edu*
Dietary specialization on the molecular level: comparative transcriptomics of prickleback fishes (Stichaeidae) with different diets
Despite obvious whole animal, tissue level, and biochemical differences among species with different diets, dietary specialization has molecular underpinnings that are not well understood. In this project, we used comparative transcriptomics of pancreatic and intestinal tissues to observe how prickleback fishes (Stichaeidae) achieve dietary-driven differences in gut size and function. With dietary variation among sympatric species, sister taxa with different diets, and convergent evolution of herbivory, the Stichaeidae is an appropriate system in which to study the genetic underpinnings of dietary specialization. *Cebidichthys violaceus* (herbivore), *Xiphister mucosus* (herbivore), *X. atropurpureus* (omnivore), and the carnivorous *Anoplarchus purpurescens* were captured during a single low-tide series on the central California coast. Using the Illumina platform, transcriptomes were sequenced for the two tissues from two individuals per species, and genome-driven assemblies were performed using the *C. violaceus* genome as the reference. Analyses are underway, but we will present data on differential expression, and enrichment of genes involved in digestion and absorption of nutrients. We have previously observed differences in gut size and function in these species, and recently reported gene copy number variation for the digestive enzyme amylase, which partially explains variation in biochemical activity levels of this enzyme in these same species. This broader transcriptomic analysis will allow us to extend our coverage beyond a single digestive enzyme gene to the multitude of digestive and absorptive processes, and will provide insight into how vertebrates specialize to use specific resources.

P2.40 GHAHRAMANI, ZN*; TIMOTHY, M; VARUGHESE, J; ARAFA, F; SISNEROS, JA; FORLANO, PM; CUNY Graduate Center, CUNY Brooklyn, Univ. of Washington; *zackgmani@gmail.com*
Forebrain Dopamine Neurons are Preferentially Responsive to Advertisement Calls in Sneaker Male Midshipman Fish
Catecholamines (CAs) are a conserved group of neurochemicals (including dopamine and noradrenaline) that are well-established modulators of neural circuits associated with various motivated sociosexual behaviors, including intraspecific vocal communication. The plainfin midshipman fish, *Porichthys notatus*, is an exceptional model for investigating mechanisms underlying vertebrate vocal behavior because production and recognition of social acoustic signals is crucial to their reproductive success. There are two male sexual phenotypes with corresponding alternative mating strategies: type I males court females into nests with advertisement calls or "hums" while type II males sneak spawn in competition with larger type Is. While CA circuitry may help assess the salience of social acoustic stimuli, it is unknown whether specific CA nuclei respond differently to attractive (hum) versus unattractive (grunt) calls. We tested the hypothesis that various CA nuclei would be differentially responsive to divergent social-acoustic signals in type II males. Sneaker males were exposed to playbacks of field recorded advertisement hums, agonistic grunts, or ambient noise. cFos (an immediate early gene product that is a proxy for neural activation) was quantified within CA nuclei by double labeling with tyrosine hydroxylase, the rate-limiting enzyme in CA synthesis. Results show activity in two populations of forebrain dopamine neurons were higher when exposed to hums than compared to ambient noise, suggesting that hums preferentially activate these nuclei. These data support specific CA nuclei as modulators of social acoustic driven behaviors.

131.6 GHANIZADEH KAZEROUNI, EN*; E. FRANKLIN, CR; SEEBACHER, FR; University of Sydney, Sydney, University of Queensland, Brisbane; *ensiyeh.ghanizadeh@sydney.edu.au*
Parental Exposure to UV-B Affects Offspring Responses
The environment experienced by parents can affect offspring phenotypes. Such developmental plasticity is beneficial when it matches offspring responses to their prevailing environment. Developmental plasticity may be detrimental if there is a mismatch between parental and offspring environments. However, reversible acclimation could compensate for a developmental mismatch. UV-B radiation damages cells directly and by increasing reactive oxygen species (ROS) formation. Animals can acclimate their antioxidant defences to reduce ROS-induced damage. Additionally, there are indications that the developmental environment can influence ROS defences, which could enhance performance and fitness of offspring. Our aim was to test whether parental exposure to UV-B modulates offspring ROS defence mechanisms to reduce the negative effects of UV-B. Exposing guppies (Poecilia reticulata) to UV-B increased the resilience of their offspring to UV-B. When exposed to UV-B, offspring from parents also exposed to UV-B had significantly greater sustained swimming performance compared to control(no-UV-B) which was paralleled by higher catalase activity and glutathione concentrations, and reduced ROS damage to membranes and proteins. Parental exposure to UV-B did not affect offspring superoxide dismutase activity, resting and active metabolic rates, or their size. However, parental exposure to UV-B increased damage to proteins and infection rates by white spot fungus in control offspring. We showed that parental exposure to UV-B can be beneficial for offspring in environments exposed to UV-B. However, the trade-off between the beneficial effects on offspring in UV-B environment and increased susceptibility to infection in offspring in no-UV-B environment can be important in determining the resilience of populations in variable environments.

137.6 GIBBONS, TC*; RUDMAN, SM; SCHULTE, PM; University of British Columbia; *gibbons@zoology.ubc.ca*
Cold and Diluted: Evidence for Evolution in Response to the Interactive Effects of Temperature and Salinity in Threespine Stickleback
Colonization of new environments exposes organisms to novel combinations of abiotic factors that have the potential to drive adaptive divergence, although studies investigating the interactive effects of multiple abiotic factors on the evolution of physiological traits remain rare. Here we examine the effects of low salinity, low temperature, and the interaction between these factors on the growth of three North American populations of the threespine stickleback fish (*Gasterosteus aculeatus*) representative of the putative ancestral marine and anadromous ecotypes and the derived freshwater ecotype. In north-temperate freshwater habitats, stickleback experience a combination of low salinity and low winter temperatures that are not experienced by the ancestral marine and anadromous forms. Here we show that both salinity and temperature and the interaction between them have stronger negative effects on the marine and anadromous populations compared to the freshwater population. Freshwater stickleback showed only a small (~10%) reduction in specific growth rate (SGR) for mass when exposed to 4°C, while marine and anadromous stickleback showed sharp declines in SGR (82% and 74% respectively) under these same conditions. The modest decreases in growth rate in freshwater stickleback with exposure to low winter temperatures in fresh water strongly suggest that this population has the capacity for physiological compensation to offset the negative thermodynamic effects of low temperature on growth, which is consistent with adaptive evolution in response to the interactive effects of low salinity and low temperature during freshwater colonization.

129.7 GIBSON, JC*; YE, D; SUAREZ, AV; University of Illinois at Urbana-Champaign; *jcgibso2@illinois.edu*

Kinematics, Scaling and Fatigue of Mandible Strike Performance in a Polymorphic Trap-Jaw Ant Daceton armigerum

Power-amplifying "trap-jaw" mandibles have independently evolved multiple times in ants (Hymenoptera: Formicidae). Nearly all trap-jaw ant taxa consist of small colonies of monomorphic workers that forage solitarily. An exception to this pattern is the ant *Daceton armigerum* . *Daceton* colonies can have thousands of individuals and their continuously polymorphic workers will cooperate to retrieve prey. In this study we characterize intra-specific scaling of strike kinematics and fatigue in mandible performance in this arboreal trap-jaw ant that exhibits a threefold difference in body size between the smallest and largest workers. Strike duration and maximum rotational velocity scale positively and negatively with body size, respectively. Maximum rotational kinetic energy scales positively with body size, suggesting that mandible mass and not maximum velocity drives energetic performance of strikes. The time interval between strikes, but not strike performance itself, increases with continuous stimulation of strikes, suggesting that the loading mechanism of the mandibles fatigues with continuous stimulation but the energetic output of the strike is conserved.

140.3 GIDMARK, NJ*; ORSBON, CP; ROSS, CF; Knox College, University of Chicago; *gidmark@knox.edu*

High bite forces maintained across gapes may circumvent length-tension constraints via dynamic architecture in Macaque monkey jaws.

Biting forces exerted by an animal are the product of skeletal morphology (jaw mechanical leverage, joint architecture, muscle insertion angle, etc) and muscular force input. Within an individual, skeletal morphology remains static; by contrast, force production of the muscle can be dynamic because of the physiological constraints of skeletal muscle. We examined how the force-length relationship of muscle relates to biting performance across gapes of Rhesus macaque (*Macaca mulatta*) monkeys by measuring bite force during supra-maximal stimulation of the nerve to the masseter muscle via nerve cuff. In two individuals (one male, one female), bite force varied only slightly (less than 25% drop) across gapes, despite a nearly 50% change in whole-muscle length from min to maximum gape. Markers within the muscle (filmed with X-ray video and integrated in XROMM analysis of skull and mandible postures) showed that at large gapes, markers were more in line with the line of action of the muscle-tendon-unit, suggesting decreasing pennation angles with increasing gape. Using fatigue testing, we demonstrated that decreases in force had the similar effect on muscle shape of decreasing pennation angles. These results suggest that fibers rotate within a muscle relative to the line of action in macaque masseter muscles, and this rotation is driven through both active (i.e. fiber shortening and force production) and passive (i.e. elastic) mechanisms. These influences could extend the range of gapes at which macaques bite at or near optimal fiber length. Further analyses will incorporate contrast-enhanced CT scans to quantitatively determine fiber angles and lengths.

68.7 GIFFORD, ME*; ROBINSON, CD; CLAY, TA; University of Central Arkansas, University of Tulsa; *megifford@uca.edu*

The influence of invasive fire ants on survival, space use, and patterns of natural selection in juvenile lizards

Invasive species have altered biotic communities exposing native species to new selective pressures. The consequences of invasive species establishment on native species are variable and include direct evolutionary changes (adaptation, hybridization) and indirect responses (behavioral and trait shifts, competitive exclusion, and extinction). An important invasive insect is the red imported fire ant, *Solenopsis invicta*; a species that was accidentally introduced into the southern United States in the 1930s from South America that has now expanded its range to cover much of the southeastern USA. Historically it has been difficult to study the impact of fire ants on vertebrate populations generally due to the lack of baseline data. However, some recent work has taken advantage of the well-documented invasion history of this insect and, using a comparative approach, determined that some species appear to be undergoing rapid local adaptation to fire ants in a suite of morphological, physiological, and behavioral traits. Despite demonstration of these comparative patterns, there have been few "controlled" experiments to date that explore the influence of fire ants on vertebrates in natural populations. In this study we take advantage of natural variation in fire ant density on experimental islands to examine the influence of fire ants on hatchling/juvenile lizard mortality, geographic space use, and patterns of natural selection. Increased fire ant density drastically reduces juvenile lizard survival across independent populations and spatially within populations. Due to mortality, fire ant distributions have a significant impact on the spatial distribution of lizards. Finally, fire ants appear to influence the form and magnitude of selection on some phenotypic traits, but not others.

129.3 GIGNAC, PM*; ERICKSON, GM; Oklahoma State University CHS, Florida State University; *paul.gignac@okstate.edu*

The Biomechanics Behind Extreme Osteophagy in Tyrannosaurus rex

Most carnivorous mammals can pulverize skeletal elements by generating tooth pressures between occluding teeth exceeding cortical bone shear strength, from which access to marrow and phosphatic salts is gained. Conversely, carnivorous reptiles have non-occluding dentitions engendering negligible bone damaged during feeding. As a result, reptilian predators often consume bones in their entirety. Nevertheless, the giant (13 m) theropod dinosaur *Tyrannosaurus rex* stands out in not only habitually biting deeply into bones, but also pulverizing and digesting them. How this mammal-like capacity was possible in the absence of dental occlusion is not known. To provide the answer we: (1) examined the crania and dentitions of specimens spanning the entire known adult size range for the taxon; (2) characterized the contact areas along the prominent maxillary tooth crowns used to fracture bones during feeding; (3) reconstructed the 3-D muscle architecture, based on Crocodylia and Aves; (4) determined muscle forces, using an experimentally validated, extant archosaurian jaw adductor muscle model; (5) size-scaled muscle forces and quantified the lever mechanics of each jaw to estimate specimen-specific bite-force capacities; (6) deduced pressure generation as the teeth penetrated bones; and (7) considered the failure properties of bone to determine how dental and palatal contact configurations facilitated skeletal element fragmentation. Bone pulverization was made possible through: (1) prodigious bite forces (8,526-34,552 N) and tooth pressures (718-2,974 MPa), promoting crack propagation, (2) dental configurations localizing shear stresses, and (3) repetitive biting. These capacities allowed *T. rex* to finely fragment bones, unlike any other animal, and to exploit large dinosaur carcasses for sustenance.

38.2 GILBERT, AL*; MILES, DB; Ohio University; *anthony.gilbert09@gmail.com*

Natural Selection on Thermal Preference and Performance over a Rapid Timescale

Climate change is radically transforming the thermal quality of global habitats. Changes in ambient temperature due to anthropogenic climate change portend to alter species activity patterns, raise field-active body temperatures, and modify their performance capacities. Whereas species have already altered their distributions or phenology to cope with changing environments, the evidence for physiological traits evolving in response to rising temperatures is limited. When organisms specialized to narrow thermal niches prefer and are active at body temperatures close to their upper thresholds for activity and function, shifts in the operative temperature distribution of thermal environments may result in a severe reduction in performance capacity. As a result, natural selection in altered thermal environments should be strong. However, many models have suggested the likelihood of thermal adaptation is low, because of limited variation among individuals. Here, we estimate the strength and form of natural selection on major thermal traits linked with the ability of organisms to exploit environments exceeding their physiological limits. We detected significant directional selection favoring lizards with warmer thermal preferences and greater sprint performance at their optimal temperature. Our analyses also revealed convex correlational selection between thermal preference and critical thermal maxima. Assuming thermal traits are heritable, we conclude evolutionary adaptation may be a viable mechanism of long-term persistence in altered thermal environments.

P3.82 GILCHRIST, S. L.; New College of Florida; *gilchrist@ncf.edu*

Up a Tree: Comapartive Shell use of Land Hermit Crabs at Cayos Cochinos, Bay Islands, Honduras

Typical population counts of land hermit crabs are made from intertidal and ground areas. Examining shell use by hermit crabs which are found in trees is rarely distinguished in these counts. The shell is a critical resource on land providing not only protection from predation but also a protection from desiccation. Shell characteristics of hermit crabs collected from trees and other plants compared to those found on the ground reveal some interesting differences, especially for female crabs.

P3.89 GILES, M*; KURNATH, P; DEARING, MD; University of Utah; *mandy@giles.red*

Chill Out: Mammalian Herbivore Use of Microclimates when Challenged by Dietary Plant Toxins

Rising ambient temperatures pose a novel threat to herbivorous mammals. Higher temperatures interact with mammalian physiology in such a way that poisonous compounds, like dietary plant toxins these mammals face at every meal, become more potent. This phenomenon is known as temperature-dependent toxicity (TDT). While the mechanism and effects of TDT have been previously investigated, it remains unknown whether mammalian herbivores would be able to mitigate the negative impacts of TDT by using cooler refugia in their natural environment. We investigated the use of cooler microclimates with a population of desert woodrats (*Neotoma lepida*) that inhabit the Mojave Desert and feed on creosote bush (*Larrea tridentata*). We predicted that woodrats would use cooler microclimates when provided access, and would show improved performance compared to woodrats without microclimate access. The effect of dietary creosote toxins on microclimate use and the influence of microclimate access on food intake and body mass maintenance were determined in a laboratory-based experiment. Woodrats did utilize cooler microclimates when provided access, but dietary creosote toxins did not appear to alter the behavior of the woodrats. Access to cooler microclimates did not affect food intake but did result in better defense of body mass compared to woodrats without microclimate access. These results suggest that cooler microclimates could provide a means to mitigate TDT through improved maintenance of body mass loss. More analysis is needed to better understand how woodrats use cooler microclimates. Understanding how mammalian herbivores interact with their environment is imperative to advance the field of plant-herbivore interactions as well as for management policies, especially during a period of climate change.

P3.83 GILLIAND, SC*; PECHENIK, JP; Tufts University, Medford, MA; *sarah.gilliand@tufts.edu*

The impact of changing water temperature and salinity on shell selection by the hermit crab Pagurus longicarpus

In Massachusetts, surface temperature and precipitation are both expected to increase in the coming years. For intertidal organisms, these changes will be felt most strongly in tide pools at low tide. A hot, sunny day will see rising temperatures and increasing salinity in a tide pool, while a rainy day will lower salinities. The hermit crab *Pagurus longicarpus* is found both intertidally and subtidally along the east coast of the U.S., and requires access to empty gastropod shells for protection. Studies have shown the limits of hermit crabs' abilities to survive at temperature and salinity extremes, but how might rapid, non-lethal shifts in temperature and salinity affect their shell-selection behavior? We tested the effects of such changes (temperatures ranging from 14°C to 33°C and salinities ranging from 20 ppt to 40 ppt) on their ability to select high quality shells that would be most likely to protect them from predators and desiccation. Each crab was given a choice between an intact shell of ideal size, a shell of ideal size with a drill hole, and a shell ¾ of the ideal size. Trials were run in which the crabs began without shells, and also in which the crabs began in either drilled or small shells. Increasing the temperature from 21°C to 30°C had little effect on shell selection behavior, but increasing the temperature to 33°C had a noticeable effect: those crabs that managed to occupy the best shell took much longer to do so. Lowering the temperature had a noticeable effect when the crabs started off in the small shells, and raising and lowering the salinity had the strongest effect when crabs started off in drilled shells.

S1.10 GILMAN, Sarah E.; Claremont McKenna College; *sgilman@kecksci.claremont.edu*
Indirect Effects of Temperature in Rocky Intertidal Communities: When Do They Matter?
Predicting the effects of climate change on species and communities remains a pre-eminent challenge for biologists. Biotic interactions are widely recognized as an important modulator of species' responses to climate change, but we are only just beginning to appreciate the complexity of ways that both climate can influence a species interaction and that species interactions can influence organismal responses to climate change. The enormous potential numbers of indirect effects any particular species might experience makes it unfeasible to incorporate all of them into predictions of climate change responses for any one species, let alone a whole community; yet, ignoring indirect effects may lead to woefully inaccurate predictions of the effects of climate change. In this talk I will review indirect effects of changing temperatures that have been reported from temperate rocky intertidal systems, with an emphasis on mussel and barnacle communities. I will discuss ways to narrow the multitude of potential indirect effects to a shorter list of more critical effects. By focusing only on those effects that alter a species' persistence in a system, rather than aspects of individual success, we may be able to generate predictions that accurately incorporate indirect effects.

P3.194 GIRAUDEAU, M*; ZIEGLER, AK; DUCATEZ, S; MCGRAW , KJ; TSCHIRREN, B; GIRAUDEAU, Mathie; ASU; *giraudeau.mathieu@gmail.com*
Interactive and Long-term Effects of Yolk Androgens and Antioxidants in Birds
Conditions experienced during prenatal development can influence an individual's developmental trajectory and have long-term effects on its physiology, morphology, and behavior, ultimately influencing its fitness. Maternally transmitted resources are important mediators of such prenatal effects, but the potential interactive effects among them in shaping offspring phenotype have never been studied. Maternally derived testosterone is known to stimulate growth, but these benefits may be counterbalanced by an increase in the production of reactive oxygen species (ROS). Maternally transmitted antioxidants might have the capacity to scavenge ROS and thereby buffer an increase in oxidative stress caused by prenatal exposure to high testosterone levels. Here, we experimentally tested for such interactive effects between maternal yolk testosterone and carotenoid in Japanese quail (Coturnix japonica). We found that hatching mass was reduced and reactive oxygen metabolites levels increased in chicks from eggs injected with either testosterone or carotenoid. However, when both egg compounds were manipulated simultaneously, hatching mass and reactive oxygen metabolites levels were not affected, showing that both carotenoid and testosterone lose their detrimental effects when the ratio between the two compounds is balanced. In line with these results, we found that maternally-transmitted androgens and antioxidants are co-adjusted within eggs in an inter-specific comparative analysis on birds' egg yolk composition. Finally, we found long-term effects of our yolk carotenoid and testosterone manipulations on testes size and maternal investment decisions, showing that these maternally-transmitted compounds have organizational effects that last until adulthood.

P3.100 GLASS, JR*; DUELL, ME; HARRISON, JF; Univ. of the Pacific, Ariz. State Univ., Ariz. State Univ.; *jordan_glass84@yahoo.com*
Sensible, non-suicidal nest defense by guards of a stingless bee
Nesting social groups often evolve strong defensive strategies, epitomized by the suicidal defenders of honey bees. Recent studies have found that *Tetragonisca angustula*, a small Neotropical stingless bee, employs a specialized soldier caste to defend its nest from raids by other stingless bees. In response to raiders, *T. angustula* soldiers attack and attempt to neutralize any intruder by locking onto them with their powerful jaws. This causes the raider to fall to the ground- immobilized by the defenders. The act of biting is thought to result in the death of the attached defenders, leading to suggestions that these guards are suicidal. In this study, we found that *T. angustula* defenders release and fly away when the raider stops moving (or if the point of attachment is severed); thus, these are not suicidal defenders. We also showed that the defensive response of *T. angustula* is relatively generalized towards the four stingless bee species, consistent with a system of flexible threat determination. This species must defend broadly and regularly against a wide array of raiding species; and their guarding behaviors permit effective nest defense while preserving the colony's population.

P3.54 GLASSFORD, WJ*; DALL, NR; REBEIZ, M; Columbia Univ. Medical Center, Univ. of Pittsburgh; *w.j.glassford@gmail.com*
Network Co-option and Individualization in the Evolution of a Novel Morphology
How the gene regulatory networks (GRNs) underlying morphological characters are built is a major subject of interest in the field of evolutionary developmental biology. Network co-option, a mechanism in which pre-existing transcriptional circuits are redeployed to a new developmental setting, has been proposed to facilitate the rapid evolution of GRNs. Although several examples implicate the contribution of network co-option to the evolution of novel structures, examples that analyze this process at the level of regulatory DNA are currently lacking. We study the posterior lobe, a genital structure that recently evolved within the *Drosophila melanogaster* clade. We discovered that the regulatory regions responsible for the genital activity of several posterior lobe developmental genes are also active in completely unrelated structures, including the larval posterior spiracles and embryonic midgut. Further, we identified several transcription factor binding sites necessary for both the derived and ancestral activities, providing strong molecular evidence for network co-option. One major challenge concerning the network co-option mechanism, however, is that it is predicted to create pleiotropic constraint between the derived and ancestral networks. To address this, we analyzed the activity of co-opted regulatory DNA from species exhibiting highly-divergent posterior lobe morphologies. We discovered modifications to co-opted regulatory DNA that altered only genital activity, indicating that it is possible to incur mutations that enact modular effects to the derived tissue without disrupting the ancestral activity.

103.3 GLEASON, LU*; MILLER, LP; WINNIKOFF, J; SOMERO, G; YANCEY, PH; DOWD, WW; Loyola Marymount University, San Jose State University, Hopkins Marine Station of Stanford University, Hopkins Marine Station of Stanford University, Whitman College; *lani.gleason@lmu.edu*

Individual Thermal Histories of Intertidal Mussels Correlate with Metrics of Oxidative Macromolecular Damage and with Levels of a Thermoprotective Osmolyte

To investigate the environmental drivers influencing the physiological status of individual *Mytilus californianus* mussels, we developed a monitoring system to simultaneously record body temperature and valve gaping behavior in the field. Thirty individuals were selected from one of two mussel beds (wave-exposed and wave-protected) that differ in thermal regime. Individuals from each source site were deployed at two locations (near the lower and upper edges of the mussel zone) and in a nearby, continuously submerged tidepool. Following a 23-d outplant period measures of oxidative damage to DNA and lipids and tissue concentrations of potentially thermoprotective organic osmolytes were obtained from each individual. Individual thermal history (mean daily maximum temperature) was positively correlated with oxidative DNA damage. In contrast, lipid peroxidation damage was weakly positively correlated only with the peak temperature in the 24h prior to sampling. Furthermore, thermal history was positively correlated with tissue concentrations of the osmolyte taurine. Source site differences were only apparent in the tidepool site, wherein mussels from the protected source habitat that spent a significantly higher percentage of time with their shell valves open also had higher DNA damage than individuals from the exposed habitat. Overall, these results demonstrate that recent experience contributes to inter-individual physiological variation, although different metrics follow unique kinetics of accumulation and repair and thus respond to environmental stress at different timescales.

P2.234 GLEISS, AC; POTVIN, J*; GOLDBOGEN, JA; Murdoch University, University of St Louis, Stanford University; *a.gleiss@murdoch.edu.au*

Physical trade-offs shape the evolution of buoyancy control in sharks

Buoyancy control is a fundamental aspect of aquatic life that has major implications for locomotor performance and ecological niche. Unlike terrestrial animals, the densities of aquatic animals are similar to the supporting fluid, thus even small changes in body density may have profound effects on the energetic costs of locomotion. Here we analyzed the evolution of body composition in 32 shark species to study buoyancy control and its effects on locomotor performance. Our comparative phylogenetic analyses indicate that although lean tissue is isometric, liver volume exhibits positive allometry, suggesting that larger sharks evolved bulkier body compositions by adding lipids to lean tissue rather than replacing lean for lipid. Furthermore, we revealed a continuum of buoyancy control strategies that ranged from more buoyant sharks in deeper ecosystems to relatively denser sharks with small livers in epipelagic habitats. Across this eco-morphological spectrum, our hydrodynamic analyses suggest that steady swimming drag and swimming economy is reduced for animals closer to neutral buoyancy and drag against unsteady swimming is reduced for sharks with greater negative buoyancy, resulting in greater burst swimming capacity and agility. This suggests that the selection for locomotor capacity to be relaxed in deeper habitats and/or selection for greater economy of movement to be increased. Moreover, the hydrodynamics of both steady and unsteady swimming appear independent of scale, implying that changes in locomotor behavior with size alter selective forces shaping body composition. These physical trade-offs associated with buoyancy may have played a major role in shaping the evolution of body condition, locomotor performance, and ecological niche in this diverse clade of marine fishes.

P3.102 GODFREY, R. K.*; GRONENBERG, W.; University of Arizona; *rkeatinggodfrey@email.arizona.edu*

Reliance on social information and trail pheromone processing in two species of Dolichoderinae ants

Ants rely on a combination of recent experience (private information) and signals from conspecifics (social information) to locate and exploit food resources. Theoretically there exists a tradeoff between the relative valuation of these kinds of information, as a strong bias for social information can lead to rapid exploitation of resources, but may result in non-optimal resource selection. To better understand how reliance on social information varies in ant species with different resource exploitation strategies, we study qualities of and response to trail pheromones, along with antennal lobe anatomy in two species of Sonoran Desert ants. The first, *Dorymyrmex bicolor* relies largely on individual foragers and small group recruitment, whereas the closely related species, *Forelius mccookii*, exhibits mass-recruitment foraging, forming foraging trails comprised of thousands of individuals. We predict relative reliance on social information will be higher in the mass-recruiting species, with individuals of *F. mcckooii* exhibiting higher pheromone trail choice consistency. In this study we focus on conspecific communication to determine when foragers decide to recruit nestmates, whether social signals are qualitatively related to resource value, and which factors predict propensity to follow social information. Additionally, we describe antennal lobe anatomy in these two species to test if differences in relative investment in particular glomeruli reflect reliance on social information.

68.6 GOEPPNER, SR*; LUTTBEG, B; Oklahoma State University; *scott.goeppner@okstate.edu*

Impacts of food restriction and predator cue exposure on individual and offspring shell morphology in the pond snail Physa acuta

We have recently found that physid snails exposed to predator cues produce offspring with increased crush resistance, a potential example of an anticipatory maternal effect. However, predator cues also cause *Physa* snails to reduce foraging and spend more time engaged in anti-predator behavior. We tested whether observed maternal effects were directly induced by predator cues or were a byproduct of reduced foraging by the parents. We exposed F1 snails to early life predator treatments and food restriction treatments in a full factorial design. Predator treatments were either non-lethal predator cues from the southern plains crayfish (P) or control cues (C) consisting of dechlorinated water. Food treatments were a full food (F) treatment (individuals were fed ~5mg of algae wafer twice a week) or a food restriction (S) treatment (individuals were fed ~5mg of algae wafer once a week). The treatments were applied for four weeks, after which all individuals were switched to the CF condition. After eight weeks, we mated F1 snails of the same treatment and collected the eggs to produce an F2 generation. We raised F2 snails from all treatments in a common garden environment with no cues, and ad-libitum food. For the F1 and F2 snails, we measured the shape, size, and crush resistance of their shells. In the F1 snails we found that predator cues changed shell shape regardless of food restriction, and food restriction reduced crush resistance regardless of predator cues. In the F2 snails, we found that parental predator and food treatments had an interactive effect with food restriction causing an increase in crush resistance if the parents were not exposed to predators and no change in crush resistance if the parents were exposed to predators. We provide informational and resource based explanations for our results.

134.7 GOESSLING, JM; MENDONCA, MT*; APPEL, AG; Auburn University; *goessling@auburn.edu*
Effects of dormancy and temperature on metabolic parameters in Gopher Tortoises, Gopherus polyphemus: Does immune state match metabolic rate?
Because energy is the basic unit of physiological processes, understanding differences in energy usage may offer insight into selective pressures across physiological states. *Gopherus polyphemus*, Gopher Tortoise, has been shown to significantly alter immunity as a result of acclimation to winter dormancy, a pattern which is present across ectothermic vertebrate taxa. Herein, we were interested in assessing the metabolic consequences of winter acclimation in this species to determine if observed reduced immunity in dormancy confers a measurable level of energy conservation. We assessed oxygen (O2) consumption, carbon dioxide (CO2) production, and respiratory quotient (RQ; the ratio of CO2 production to O2 consumption) in *G. polyphemus* at two temperatures (12. 5°C and 32.5°C) and two seasonal acclimation states (winter and summer). We found that season did not have a direct effect on either O2 consumption or CO2 production, but that RQ was significantly elevated in animals at the colder temperature ($P < 0.001$). Additionally, we found very high RQs (> 1.0) in cold-acclimated animals during dormancy. The observed high RQs in this species are likely a result of anaerobic digestion occurring in the gut, as we documented significant anaerobic carbon dioxide production in fecal samples. Oxygen consumption was highest in animals at the warmer temperature, and the Q10 for O2 consumption in animals in this study was 2.34. While we failed to identify a reduced pattern of metabolism during dormancy, results from this study further demonstrate important physiological modulation between dormancy and activity in this species of conservation concern.

P3.137 GOFF, CB*; GABOR, CR; WALLS, SC; Texas State University, San Marcos, US Geological Survey, Gainesville, FL; *goff@txstate.edu*
Core vs. Periphery: Linking Environmental Variables and Stress with Amphibian Declines
Climate change has become a significant driver in ecology, and is associated with changes in environmental factors like temperature, humidity, precipitation, and sea level rise. In addition, anthropogenic disturbances also alter habitat and reduce habitat quality. These factors can limit population ranges with optimum habitat in the core of the range and lower quality habitat along the range periphery. One mechanism to assess how individuals and populations respond to changing conditions is to assess their physiological health. We obtained baseline and stress induced water-borne corticosterone (CORT) release rates for *Pseudacris ornata* (Ornate Chorus Frog) tadpoles from multiple sites in four locations across an east-west transect in northern Florida and one location in southern Georgia. We hypothesized that locations in the range periphery where populations have been declining would not show a stress response (indicating chronic stress) and that baseline CORT release rates from peripheral populations would differ from the more stable populations in the range core. We found that baseline CORT release rates were lower in core versus peripheral locations and that CORT release rates increased with lower water quality (higher water temp, tds, and conductivity). Higher baseline CORT in lower quality sites with lower water quality may partially mediate the observed population declines in peripheral populations.

P2.189 GOLDEN, AM*; BONISOLI-ALQUATI, A; MOUSSEAU, T; GOLDEN, Alexan; University of South Carolina, Columbia, Louisiana State University; *agolden@email.sc.edu*
Developmental Effects of Low-Dose Radiation on Dragonflies in Chernobyl and Fukushima
The Chernobyl and Fukushima nuclear explosion disasters created large natural laboratories for the long-term study of low-dose radiation. Chronic exposure has been shown to negatively affect fitness and development in both vertebrate and invertebrate species from the Chernobyl region, in addition to humans. Radiation is also known to cause oxidative stress, an imbalance between reactive oxygen species (ROS) and antioxidant defenses, which can lead to increased mutation rates. Mutational events can cause developmental instability, which can be reliably tracked by fluctuating asymmetry (FA) and other developmental malformations. Fluctuating asymmetry has been shown in insect species to be an indicator of oxidative stress. For this experiment, dragonflies were chosen as a study species, due to their short generational times and discrete developmental unit (wings). We captured dragonflies of several species from the Chernobyl Exclusion Zone in the Ukraine, as well as from Fukushima, Japan. Analysis of fluctuating asymmetry was conducted using sixteen landmark points on the top and bottom wings, which correspond to homologous vein intersections, as markers for measurement of fluctuating asymmetry and centroid size. Preliminary results of data analysis from dragonflies in Chernobyl indicate some significant results. Qualitative analysis also shows frequent abnormalities in venation patterns of Chernobyl and Fukushima species. This project has been the first step in assembling a multi-year database of landmark data from Chernobyl and Fukushima.

50.7 GOLDSTEIN, JG*; CARLONI, J; KIBLER, RD; Wells National Estuarine Research Reserve (NOAA), Wells, ME, New Hampshire Fish & Game, Durham, NH; *jsgoldstein2@gmail.com*
A Fishery in Flux: Claw Removal and its Impacts on Survivorship, Behavior, and Physiological Stress in Jonah Crab Cancer borealis
Found in coastal and shelf waters along the Atlantic coast of North America, from Newfoundland to Florida, Jonah crab *Cancer borealis* have been captured as incidental bycatch in the New England lobster industry for over 80 years. In the last 20 years however, Jonah crabs have become an alternative fishery target and landings have more than quadrupled. This has necessitated evaluation of the current status and prospective long-term health of the fishery. The biological implications of harvesting Jonah crab through the live removal of claws remain mostly unknown. The goal of this ongoing research is to evaluate current harvest practices (claw removal) and the implications on the health and behavior of Jonah crabs. Preliminary results from laboratory trials ($n = 232$ total crabs) suggest that double-claw removal incurs markedly more mortality (~74 %) compared with single-claw removal (~56 %) and control animals (~19 %). Physiological stress, assessed through concurrent haemolymph analyses suggest elevated levels of glucose and lactate in de-clawed crabs. Continued studies on behavior (feeding) and growth are ongoing in an effort to better understand Jonah crabs and manage this rapidly developing fishery in New England waters.

P2.235 GOLDSTEIN, JG*; DUBOFSKY, EA; Wells National Estuarine Research Reserve (NOAA), Wells, ME, Department of Biological Sciences, New England Institute of Technology, East Greenwich, RI; *jsgoldstein2@gmail.com*

A Life of Rhythm and Blues: Correlates and Changes in Activity Patterns and Circadian Rhythms in Tropical Slipper Lobsters

Circadian rhythms are controlled by an internal clock and are molecular, physiological, or behavioral events that occur predictably. The conservation of such rhythms in a variety of plants and animals suggests that circadian clocks help organisms to anticipate and synchronize to daily environmental changes, providing tremendous adaptive advantage. The prevalence and variability of circadian rhythms in slipper lobsters remains understudied and elusive. Slipper lobsters *Scyllarides spp.* are highly cryptic, but sometimes gregarious animals that shelter in a variety of both soft (sand) and hard (caves) habitats with minimal light. The primary goal of this work is to provide better resolution of activity patterns during light-dark cycles in juvenile tropical slipper lobsters and to examine two scenarios that may prompt changes to their overall activity and associated circadian rhythms. First, we evaluated the activity patterns and circadian rhythms for lobsters in group-settings (n = 3-4) versus those kept individually (n = 6) to test the hypothesis that social behavior has an effect on activity patterns. Second, we simulated predation pressure to assess if these cues modulate lobster behavior, thereby altering their circadian clock. These lab-based studies were assessed using a combination of time-lapse video along with actogram and periodogram analyses. These ongoing studies will contribute a better understanding of some of the factors that initiate and potentially alter activity patterns and modify circadian rhythms in lobsters. Our results may also provide correlates for other animal-based models of circadian behavior.

P2.74 GONZALEZ-GOMEZ, PL*; ECHEVERRIA, V; ESTADES, CF; PEREZ, JH; KRAUSE, JS; WINGFIELD, JC; Univ. of California, Davis, Universidad de Chile, Univ. of California, Davis ; *plgonzalezgomez@gmail.com*

Timing of Life History Stages and Endocrine Mechanisms in Seasonal versus Aseasonal Environments

Organisms inhabiting characteristically unique environments match their life history traits to predictable environmental events associated with habitat variability. Thus, animals rely on cues such as change in annual photoperiod, rainfall, ambient temperature and other local factors to schedule life history stages (LHSs) such as reproduction and molt. These processes can be energetically costly, and may not be expressed simultaneously without negative effects on fitness. Rufous-collared sparrows (*Zonotrichia capensis*) living in valleys in the Atacama Desert -one of the most stable environments ever studied-, and in the semiarid Fray Jorge National Park in the north of Chile - extremely seasonal and unpredictable - offer ideal conditions in which to examine the interplay between androgens, glucocorticoids and thyroid hormone levels and their influence on life history trade-offs. Birds in the Atacama experiencing almost no seasonal environmental cues or constraints to organize the life cycle showed overlap of LHSs, low glucocorticoids, and low androgen levels year-round. In contrast, birds in Fray Jorge region facing dramatic predictable and unpredictable environmental changes showed strict temporal division of LHSs, higher glucocorticoids and cyclic levels of androgens across the year. How individuals integrate endocrine mechanisms and timing of LHSs can be pivotal to understand how birds will manage the dramatic increase in unpredictable events linked to climate change.

P2.263 GONZALEZ-ROSARIO, J*; CHUNG, D; REES, BB; University of New Orleans, University of British Columbia; *brees@uno.edu*

Hypoxia inducible factor-1α protein increases during hypoxic exposure of killifish

Many fish face low oxygen concentrations (hypoxia) in their natural environments, and they respond to hypoxia through a variety of behavioral, physiological, and cellular mechanisms. Some of these responses involve changes in gene expression. In mammals, the hypoxia inducible factor (HIF) family of transcription factors are the "master regulators" of gene expression during hypoxia, but the study of HIF in fish has been hampered by the lack of reagents to detect this protein in non-mammalian vertebrates. In this study, we affinity purified antibodies against HIF-1α from the killifish *Fundulus heteroclitus* and used them to recover and quantify HIF-1α from killifish cells and tissues. Mass spectrometry analysis confirmed that these antibodies recognized HIF-1α in the killifish cell line, KFE-5. The protein was more abundant in nuclear extracts than cytoplasmic extracts but only minimally affected by exposure of KFE-5 cells to cobalt chloride, a hypoxic mimetic. In the closely related *F. grandis* exposed to low oxygen for 24 h HIF-1α was elevated in skeletal muscle, liver, brain, and gonad. There was considerable individual variability in the extent of the increase in tissue HIF-1α protein levels during hypoxia, suggesting individual differences in hypoxia responses among fish. These results indicate that fish respond to low oxygen exposure with increases in HIF-1α protein levels in multiple tissues and that this response varies among individuals within a species.

P2.153 GOODCHILD, CG*; DURANT, SE; Oklahoma State University; *christopher.goodchild@okstate.edu*

Food Availability and Environment Mediate Behavioral Traits of "Shy" Snails.

The animal personality hypothesis predicts that animals have limited behavioral plasticity, leading to consistent among-individual differences in behavioral responses. Previous work suggests that animal personality has broad implications for a suite of inter and intra-specific interactions. However, it remains unclear how external factors (e.g., food availability) and habituation contribute to the development and maintenance of distinct personalities. In this study, we examined the plasticity of two behaviors (i.e., boldness and exploration) in a freshwater snail (Helisoma trivolvis). We manipulated food availability and environment and thereby investigated (1) whether behaviors are state-dependent, (2) whether food availability influences habituation of behavioral responses after repeated exposures to a particular environment, and 3) whether altered behavioral responses are permanent (i.e., growth-dependent) or flexible (i.e., environment-dependent). To do so, we measured latency to emerge from shell to assign snails to bold or shy personality types. We then measured latency to emerge from shell (i.e., boldness) and activity in a novel environment (i.e., exploration) in snails after 0, 7, and 14 d of ad lib or restricted feeding. At 15 d we measured latency to emerge in a new novel environment. Regardless of food treatment, latency to emerge decreased after 14 d in all snails (i.e., snails became more bold), but introduction to a novel environment on day 15 caused snails to return to shy behaviors. Activity level was constant during the experiment for snails fed ad lib, but decreased in food-restricted snails. Activity was correlated with mass, whereas latency to emerge from shell was not correlated with mass. These data suggest that although individuals may habituate to novel environments, personality traits are retained when introduced to a new novel environment, and exploration is a state-dependent trait.

34.4 GOODCHILD, CG*; SCHMIDT, LM; DURANT, SE; Oklahoma State University; *christopher.goodchild@okstate.edu*

Animal Personality Explains Among-Individual Variation in Antipredator Strategies

The animal personality hypothesis postulates that animals have limited behavioral plasticity, and consequently, an individual's behavioral traits will be consistently expressed across different ecological contexts (e.g., predation regimes). Since there is among-individual variation in behavioral traits, individuals within a population can be characterized along behavioral axes (e.g., bold-shy axis). Because "bold" and "shy" individuals have limited behavioral plasticity, the animal personality hypothesis predicts that individuals will consistently display shy or bold behaviors, even if such behaviors are suboptimal for a particular ecological scenario. For instance, bold behaviors may be optimal if predator risk is low, or suboptimal if predation risk is high. Therefore, individuals may express compensatory traits that diminish the cost of suboptimal carryover behaviors. In this study, we examined whether animal personality influenced antipredator responses in snails exposed to a predator cue. To do so, we determined relative boldness of snails (Helisoma trivolvis) by measuring latency to re-emerge from shell. We then exposed bold and shy individuals to predator cues and measured crawl-out behavior, activity, shell crush resistance, and shell morphology. We found that bold snails exposed to a predator cue employed a crawl-out antipredator strategy, whereas shy snails remained in the predator environment and invested greater resources in shell crush resistance. Bold snails were more active and had more defensible shell morphologies. These results suggest animal personality explains within-population variation in antipredator responses. Moreover, the interaction between personality, morphology, and compensatory behaviors provides empirical evidence for state-dependent behavioral feedback loops.

109.2 GOODHEART, JA*; BAZINET, AL; VALDES, A; COLLINS, AG; CUMMINGS, MC; Univ. of Maryland, College Park, California State Polytechnic Univ., Pomona, National Oceanic and Atmospheric Administration; *jagood@umd.edu*

Eat, Prey, Evolve: Phylogenetic relationships and diet in Cladobranchia (Gastropoda: Heterobranchia).

The role of prey or host shifting as a driver of diversification in large clades of marine taxa is poorly studied within a phylogenetic framework. Cladobranchs occupy a number of marine environments including coastal reefs, where diversity is highest, but also the deep sea and highly specialized pelagic and neustonic niches. However, difficulties in reconstructing the phylogeny of Cladobranchia have limited the ability of researchers to test whether prey preference has any effect on diversification within this group. To address issues with reconstructing the phylogeny of Cladobranchia, we identify and resolve the major lineages within Cladobranchia using RNA-Seq data, and use ancestral state reconstruction and diversification analyses to better understand the evolution of prey preferences and prey switching, and test for possible association with diversification. These analyses have resolved several questions regarding the evolutionary relationships within Cladobranchia, including a monophyletic Arminida to the exclusion of *Janolus* and *Dirona*, and a clearly non-monophyletic Dendronotida. In addition, the results of the present study indicate that clades within Cladobranchia are closely allied with prey preference, but there are very few prey shifts across the evolutionary history of this group. Diversification analyses indicate little support for the hypothesis that prey shifting leads to diversification. Future research on Cladobranchia would benefit from broader taxon sampling, and combined analyses of diet preferences and prey switching, diversification, and characters that may be correlated with diversification in this group.

P1.129 GORMALLY, BM*; WRIGHT-LICHTER, J; HENRY, M; ROMERO, LM; Tufts University; *brenna.gormally@tufts.edu*

Evaluating physiological and behavioral responses to repeated stressors: testing the reactive scope model

Wild animals often cope with stressful stimuli that elicit a suite of physiological and behavioral responses. One central element to these responses is upregulation of the hypothalamic-pituitary-adrenal (HPA) axis and corticosterone (CORT) release. The immune, metabolic, cardiovascular, and behavioral systems are also intricately involved during these responses. While many mechanisms are activated to cope with stress, a comprehensive model of these responses has yet to be thoroughly tested. The reactive scope model provides a framework to understand and simplify the complicated timing of stress by separating mediator levels into four distinct categories; (1) predictive homeostasis, (2) reactive homeostasis, (3) homeostatic failure, and (4) homeostatic overload. An assumption of this model is that exposure to layered, repeated stressful stimuli cause an animal to enter the overload region more rapidly than exposure to a single stressor alone. In this study, we used house sparrows (*Passer domesticus*) to test this hypothesis by assessing CORT, immune, metabolic, and behavioral responses. Birds were exposed to four days of one stressor, followed by four days of a second (layered/repeated) stressor. Maximal physiological CORT production and microbial killing capacity decreased after repeated stress exposure, responses that align with predictions from reactive scope. Uric acid and neophobic behavior decreased after presentation of the first stressor and remained low after the repeated stressor. Although a number of metrics did not change during the protocol, none of the observed responses were opposite to those predicted by reactive scope. Overall the results provide partial support for the model.

14.7 GOUGH, WT*; FISH, FE; LEWIS, GT; BART-SMITH, H; West Chester Univ., PA, University of Virginia, University of Virginia; *wgough0788@gmail.com*

Physical Properties and Anisotropy in the Central Tissue Layer of Cetacean Tail Flukes

During swimming, cetaceans generate hydrodynamic thrust with dorso-ventral oscillations of flexible tail flukes. These flukes do not contain rigid skeletal structures. Instead, the majority of the fluke is composed of a densely packed collagenous matrix with collagen fibers running in a crisscrossing pattern along the chordwise axis. Flukes from six species of odontocete cetaceans were examined to compare the morphology and orientation of fibers in relation to the physical properties of the flukes. All species were found to have the same generalized morphology, but the pygmy sperm whale (*Kogia breviceps*) was found to have additional fibers running perpendicular along the span of the fluke. Compression tests were performed at 10%, 40%, and 70% of the span on the flukes of each species in three orientations: spanwise, chordwise, and dorso-ventral. In all species, the spanwise direction was found to be the most rigid, while the chordwise and dorso-ventral directions were found to be more pliable. Anisotropic deformation of the fluke samples always occurred in the spanwise direction when compressed in either the chordwise or dorso-ventral directions, and very little deformation was observed when the fluke samples were compressed in the spanwise direction. These results are consistent with the three-dimensional structure of the flukes that were comprised of two-dimensional sheets of material aligned tightly in a plywood-like configuration along the span of the flukes. The anisotropic properties imparted by this unique internal structure help the flukes to maintain their spanwise rigidity while allowing partial flexibility during swimming.

72.2 GRACE, J. K.*; PARENTEAU, C.; MEILLERE, A.; FROUD, L.; ANGELIER, F.; Texas A&M University, Centre d'Etudes Biologiques de Chize, CNRS, University of Rennes 1; *jkgrace@exchange.tamu.edu*

Stress, Death and the "Silver Spoon": Effects of Early-Life Stress on Growth and Immunity across Life Stages in a Wild Bird

Early-life stress has long-term effects on animal physiology, however, the magnitude and direction (i.e. positive or negative) of these effects is inconsistent across studies, probably due to variation in duration of stressors, type of stressors, and life stage at which effects are evaluated. In the wild, transient early-life stressors are likely as common as chronic stressors, yet have received less attention. Here, we investigate long-term effects of early-life transient surges in stress hormones in wild house sparrows (*Passer domesticus*). We non-invasively increased circulating corticosterone in free-living nestlings at eight, nine, and eleven days post-hatching. At fledging, all nestlings (70 nestlings from 23 nests) were taken into captivity. Body size, body condition, hematocrit, PHA-induced skin swelling, capture-restraint stress response, and mortality were analyzed at the nestling, juvenile, and adult stages. Compared to corticosterone-fed nestlings, control nestlings appear to have been given a "silver spoon". Early-life stress decreased bird size, body condition, and had long-term effects on stress-induced corticosterone. However, the magnitude of the morphological effects weakened across life stage due to phenotypic plasticity (not selective mortality). There was no effect of treatment on mortality until the adult stage, when treated birds had a higher probability of mortality than controls. Our results reveal that some, but not all, long-term effects of early-life stress may be mitigated by phenotypic plasticity.

73.7 GRADY, KO*; BOURGEON, AM; RESNER , EJ; CORNELLA, KN; BELANGER, BG; HARDY, KM; California Polytechnic State University, San Luis Obispo; *kogrady@calpoly.edu*

Effect of Oxygen-Limiting Tidal Conditions on Muscle Metabolism and Structure in the Giant Acorn Barnacle, Balanus nubilus

Crustacean muscle fibers are some of the largest cells in the animal kingdom, with fiber diameters in the giant acorn barnacle *Balanus nubilus* exceeding 3 mm. Sessile animals with extreme muscle sizes and which live in the hypoxia-inducing intertidal zone - like B. nubilus - represent ideal models for probing the effects of oxygen limitation on muscle cells. We investigated changes in metabolism and structure of *B. nubilus* muscle in response to: normoxic immersion, anoxic immersion, or air emersion, for acute (6h) or chronic (6h exposures twice daily for 2wk) time periods. Following exposure, we immediately measured hemolymph pO2, then excised tergal depressor (TD; glycolytic) and scutal adductor (SA; oxidative) muscles to determine citrate synthase (CS) activity, lactate dehydrogenase (LDH) activity, and D-lactate. We also prepared a subset of SA and TD muscles from the chronic barnacles for histological analysis of fiber diameter (Feret's), cross-sectional area (CSA), and myonuclear domain size. There was a decrease in hemolymph pO2 following 6h of anoxia, though not emersion, and this effect was more pronounced in the chronic than the acute experiment. Fiber CSA and diameter did not change significantly in either tissue, while myonuclear domain size in SA muscle was significantly lower in the anoxic and emersion groups than the normoxic control. Neither CS, nor LDH activity, showed any significant treatment effect in either tissue, whereas both muscles had significantly higher D-lactate levels after air emersion following acute (though not chronic) exposure. Thus far, our findings indicate that emersion is only mildly oxygen-limiting for *B. nubilus*, and that significant muscle plasticity is occurring during chronic emersion and anoxia.

80.2 GRAHAM, JL*; COOK, NJ; NEEDHAM, KB; HAU, M; GREIVES, TJ; North Dakota State Univ., Benedictine College, Max Planck Institute; *jessica.l.graham@ndsu.edu*

Early to Rise, Early to Breed: A Role for Endogenous Daily Rhythms in Seasonal Reproduction

Temperate-zone vertebrates use initial and local predictive cues to time reproduction to optimal breeding conditions, yet individual variation in timing of reproductive output (i.e. clutch initiation) is observed. Numerous laboratory studies have revealed that light experienced during a critical window of the circadian period is capable of influencing reproductive physiology. Interestingly, laboratory studies have also revealed significant individual variation in endogenous circadian rhythms. However, whether this individual variation in endogenous daily rhythms influences variation in seasonal responses to light remains largely unexplored in the wild. Here we test the hypothesis that individual variation in endogenous timing phenotypes recorded in nature (i.e. chronotype) are linked with variation in seasonal timing of breeding. To address this hypothesis we utilized incubation behavior data to identify individual patterns of awakening time in two temperate-breeding songbird species, the Great Tit (*Parus major*) and the Dark-eyed Junco (*Junco hyemalis*). We found individual awakening time to be repeatable in both species, justifying it as a consistent, measurable phenotype. Importantly, we found that females who departed from their nest earlier in the day also initiated nests earlier in the year in both species. Date of data collection and ambient temperature did not affect awakening time. Our findings suggest a role for endogenous behavioral rhythms as one mechanism underlying the observed variation in seasonal timing of breeding.

P1.119 GRAHAM, AM*; MCCRACKEN, KG; University of Miami; *graham.allie@gmail.com*

Increased purifying selection plays a dominant role in mitochondrial hypoxia adaptations of three Andean duck species

The Andes are the world's highest mountain range, second to those in Asia, which also contain the second highest plateaus, with peaks rising to an elevation of 6,961 m. These Altiplano-plateaus contain wetlands that host a number of waterfowl species, who are ideal for studying the effects of both low oxygen, and cold-stress, due to the metabolic demands associated with their high-altitude environment. This study aims to test for, and compare, the presence of signatures of high-altitude adaptation with respect to variation in the mitochondrial genomes of three Andean waterfowl species: yellow-billed pintail, cinnamon teal and speckled teal. Each lineage has independently colonized the same South American Altiplano wetlands and inter-Andean valley puna grasslands, thus providing natural replicates of independent adaptive events to high-altitude, cold-stressed, hypoxic environments. Here we test whether mitochondrial variation is linked to high-altitude adaptation in these three species, across the full mitochondrial genome. We investigate potential selective pressures at the mitogenome level in three different species of Andean waterfowl across altitudinal populations by analyzing 60 full mitochondrial genomes. In general, there is evidence of convergence at the level of selection acting to maintain the OXPHOS unit's ability to operate optimally through an increase in purifying selection. This is especially true for the speckled teal, which shows distinct signs of differential selective pressures acting on the mitochondrial genome between high- and low- altitude populations; specifically, a substantial increase in purifying selection likely due to invasion of high-altitude niches.

115.7 GRAHAM, MA*; COONEY, B; EARLEY, RL; BAKER, J; FOSTER, SA; Clark University, University of Alabama; *megraham@clarku.edu*

Evolutionary history matters: Maternal hormonal response to a natural stressor and effects on offspring growth and behavior

Maternal effects can have positive or negative effects on maternal and offspring fitness, and are likely to be influenced by the evolutionary history of a population. Here we evaluate the influence of maternal hormonal state on offspring development in three populations of threespine stickleback (*Gasterosteus aculeatus*) that differ naturally in the presence and intensity of cannibalistic foraging groups to understand how evolutionary history with a potential stressor shifts the female stress response and influences offspring phenotype. We imposed a cannibalism-related challenge (post-ovulatory egg retention) and measured subsequent maternal, egg, and fry hormone levels, as well as fry growth and behavior. Females did not show elevated cortisol with forced egg retention although decreases in testosterone and estrogen occurred, consistent with expected shifts post ovulation. Although maternal titers did not change, egg cortisol levels in one population were affected by treatment and correlated with differences in fry stress response at three months of age. In two populations, declines in maternal testosterone were paralleled in egg hormone levels. Overall, the maternal challenge significantly reduced fry growth rate and feeding performance in the first month of life, and modestly increased recovery time after a startling stimulus. While maternal response to a natural challenge did not differ between populations, the results here show evolved differences in the consequences for offspring in the face of such challenge.

83.6 GRAHAM, M*; WEISS, T; JAYNE, BC; SOCHA, JJ; Virginia Tech, Univ. of Cincinnati; *grahmich@vt.edu*

Jumping as a gap-bridging strategy in flying snakes

To move most directly between two locations, arboreal animals often must cross gaps between branches or trees. Arboreal snakes have an impressive ability to cantilever when bridging gaps, anchoring themselves posteriorly while extending the anterior body to cross the gap. Cantilevering is biomechanically constrained by the torque required to support the body, but some snakes can extend their reach using dynamic lunging. The flying snake *Chrysopelea paradisi* often initiates glides with a "J-loop" take-off, in which the snake forms a hanging curve with the anterior body and rapidly straightens to depart the branch. Such jumping, which is more energetic than lunging, could be employed in gap-bridging. Here, we used a six-camera motion-capture system (Vicon Motion Systems Ltd.) to investigate whether jumping increases the distances flying snakes are able to traverse, and if so, to determine the factors that precipitate the transition from cantilevering to jumping. Preliminary data from 96 trials suggests that *C. paradisi* uses both lunging and jumping once the snake is unable to cantilever, and that jumping increases the achievable gap distance they can cross. For one snake (mass: 68.7 g, SVL: 72 cm), cantilever failure occurred at 55% SVL, and larger gaps were successfully crossed using either lunges or J-loop jumps. For gaps of 80% SVL and above, the snake used the J-loop jump exclusively, enabling it to cross gaps of at least 100% SVL. In comparison, *Boiga irregularis*, an excellent arboreal climber, can cross a maximum gap of 64% SVL, indicating that the use of jumping may confer a greater gap-bridging ability to *C. paradisi*. Hence, jumping in *Chrysopelea* may serve as a mechanism to increase locomotor effectiveness in patchy arboreal environments, and may have evolved independently of gliding. Supported partially by NSF 1351322.

17.2 GRAVISH, N*; GAGLIARDI, F; COMBES, SA; Univ. of California, San Diego, Univ. of California, Davis; *ngravish@ucsd.edu*

Bumblebees shift into reverse: flight biomechanics and guidance in the presence of tailwinds

Foraging insects must fly through complex spatial environments while compensating for variable and often strong background airflows (i.e. wind). While navigating through environments with strong visual cues, bumblebees and honeybees regulate their airspeed to maintain a constant optic-flow rate across their compound eyes even in the presence of background airflows.Both flight performance and the regulation of speed by optic-flow have predominantly been studied when insects fly against the wind (i.e. into a headwind). Here we seek to understand the limits of flight performance and visual speed-regulation when insects navigate with strong tailwinds. We studied foraging bumblebees (*Bombus impatiens.*) that flew through a 30x30x125 cm section of a wind tunnel between their nest and a nectar feeder. We measured 3D flight kinematics in three wind conditions (0 m/s, 0.75 m/s, and 2 m/s) to test the hypothesis that bees maintain a constant optic-flow rate (and thus constant groundspeed in our experiment) despite the presence of low and high tailwinds. We observed that bees took progressively more sinuous flight paths as tailwind speed increased. However, restricting our analysis to straight flights through the chamber we observed no significant difference in flight groundspeed among the three tail wind conditions ($p = 0.34$). Bees maintained a mean groundspeed of 90.8 ± 39.0 cm/s independent of the presence of tailwinds. To regulate groundspeed in the high tailwind condition bees modulated their stroke plane by pitching upwards to counter the wind-direction. The highest tailwind (2 m/s) exceeded the bees typical ground speed (90.8 cm/s) which indicates that in these conditions bumblebees actually flew in reverse (flew at a negative airspeed) while traveling forward and maintaining constant positive groundspeed.

67.2 GRAY, BL*; WARD, MV; WILLIAMS, KA; MILES, DB; Ohio University; *bg022811@ohio.edu*

Sex-specific differences in provisioning behavior in the Hooded Warbler (Setophaga citrina)

The Hooded Warbler *Setophaga citrina* is a migratory Parulid which breeds in mature forests throughout eastern North America. Sex-specific variation in habitat use has been documented in both the tropical wintering grounds and the temperate breeding grounds. Male Hooded Warblers tend to utilize the canopy and mid-story while females tend to utilize the understory. Differences in structural complexity in the upper and lower levels presents each sex with different locomotion challenges and a unique prey base. We sought to determine whether differences in ecology exhibited by each sex correspond to differences in morphology and foraging behavior, and the implications of such differences on maternal and paternal care behaviors. We captured, uniquely marked, and collected morphological data from all adult Hooded Warblers breeding in four, 30ha study sites in southeastern Ohio. We monitored each adult bird through the 2015 and 2016 breeding seasons to locate nests, map territory boundaries, and record foraging behaviors and substrate use. We video recorded each nest for a minimum of two hours, every other day during the nestling period in order to obtain provisioning rates and prey loads brought by each adult. Finally, we quantified growth rate for each nestling and assessed the body condition of each fledgling. We present data on the relationships between adult hooded warbler morphology and ecology and how parental morphological and behavioral phenotypes affect reproductive success.

106.2 GRAYSON, P*; SACKTON, T; CLOUTIER, A; CLAMP, M; TABIN, C; EDWARDS, SV; Harvard Univ., Harvard Medical School; *pgrayson@fas.harvard.edu*

Comparative Genomics, Epigenomics, and Developmental Biology Uncover Convergent Acceleration in Putative Regulatory Regions Associated with Repeated Losses of Avian Flight

Convergent evolution results in shared, analogous phenotypes along independent lineages. Palaeognathae, a clade containing flightless ratites and volant tinamous, offers a unique opportunity to study the processes underlying convergent evolution: recent phylogenies support at least three losses of flight within the clade. Despite independent transitions to flightlessness, there are notable phenotypic similarities among ratites; for example, all ratites have reduced forelimbs and lack a sternal keel. To determine if convergent genomic changes govern convergent phenotypic changes, we have generated ten new high-quality genomes (three tinamous and seven ratites), and produced a phylogenetically based whole-genome alignment containing an additional 32 birds and non-avian reptiles. Our comparative genomic analysis uncovered many conserved non-exonic elements (CNEEs) that exhibit repeated acceleration along flightless ratite lineages, while remaining conserved in volant palaeognaths and neognaths. Since CNEEs often contain enhancers and other regulatory elements, these results suggest a strong role for regulatory evolution during these convergent losses of flight. ATAC-seq is now being carried out on the limbs of chicken (*Gallus gallus*), alongside the flightless emu (*Dromaius novaehollandiae*), and greater rhea (*Rhea americana*) to determine if candidate CNEEs: (1) exist in regions of accessible chromatin, and (2) display epigenomic differences between volant and flightless species. Putative enhancers are also being tested within a reporter construct in the developing chicken limb. This integrative approach will allow us to examine the functional developmental basis of a convergent phenotype.

41.4 GREAR, ME*; DITSCHE, P; MOTLEY, MR; University of Washington, University of Alaska, Anchorage and Friday Harbor Laboratories; *mgrear@uw.edu*

Development of a Material Constitutive Model for Killer Whale and Harbor Porpoise

Tidal energy has an immense potential for creating renewable energy and is being investigated worldwide. In the emerging field, potential environmental consequences of installing tidal turbines must be evaluated. Marine mammals often use tidal channels for feeding and traveling and may collide with the spinning blades. This study aims to quantify the soft tissue response of two marine mammal species, Southern Resident killer whale (*Orcinus orca*) and harbor porpoise (*Phocoena phocoena*), during a collision with a tidal turbine blade. Biomechanical properties of skin and blubber are needed to implement a finite element model determining the extent and severity of a turbine blade strike. Using stranded harbor porpoise and killer whale, we collected skin and blubber for post-mortem examination of their material properties. Tensile tests of the skin and blubber layers were performed on these specimens to determine tensile stiffness and tensile strength, as well as the strain rate effects on these quantities. Samples were taken in three orientations to investigate anisotropy. Both types of tissue exhibited a large plastic region, showing non-linear behavior. Compressive spherical indentation tests were performed with the composite skin and blubber layer and on the blubber layer alone to assess the difference between the tension and compression behavior. It was found that the compressive stiffness of blubber was approximately an order of magnitude lower than corresponding tensile data. These experiments were subsequently recreated using the commercial finite element solver ABAQUS to validate the numerical material constitutive models. Ultimately, the numerical models can be extrapolated to full-scale, realistic models of marine mammals to assess their susceptibility to injury from turbine blade impact or similar phenomena.

34.3 GRECIAS, L*; HEBERT, FO; BERGER, C; BARBER, I; AUBIN-HORTH, N; Université Laval, Québec, Leicester University, UK; *lucie.grecias.1@ulaval.ca*

Is the Stickleback Manipulated by its Parasitic Flatworm? Combining Phenotypic Engineering and Transcriptomic Approaches.

Sticklebacks infected by the parasitic flatworm *Schistocephalus solidus* show large changes in phenotype, including a lack of the typical behavioural response to predator presence. Interestingly, these changes occur when the parasite is ready to move to its final host (a piscivorous bird) to reproduce, which makes it an ideal model for studying the mechanisms of behavioural modification by parasites. However, whether this drastic behavior change is a by-product of facing a parasitic infection, or the result of a direct manipulation by the parasite is unknown. We used two approaches to test predictions arising from these hypotheses. First, we used phenotypic engineering to recreate the behavioural modifications using pharmacological manipulations. We were able to recreate some aspects of the behavioural modifications observed in a parasitized fish, but not others. Second, we used an RNA-Seq analysis to compare the whole-brain transcriptome of healthy, exposed, infected and pharmacologically manipulated (fluoxetine) sticklebacks, to define a genomic signature of *Schistocephalus* infection in the host brain, and to uncover overlaps in transcriptomes between infected and fluoxetine-treated fish. Our use of a combined approach to uncover the causes of behaviour modification by a parasite will contribute to shed a new light on this parasite-host interaction.

79.5 GREEN, P.A.*; PATEK, S.N.; Duke University; *patrick.a.green@duke.edu*

Mantis shrimp use ritualized sparring as an aggressive signal in escalated contests.

Animal contests dictate access to territories, mates, and other resources that influence fitness. This study examined how animals integrate contest behaviors (signals) and structures (weapons) to resolve contests. Both sexes of the mantis shrimp *Neogonodactylus bredini* use enlarged raptorial appendages as weapons in territorial contests, presenting visual displays and sparring by exchanging potentially deadly, high-force strikes with competitors that coil their telson (tailplate) in a defensive posture. We tested if telson sparring is a signal used in escalated contests by comparing behavioral sequences of competitors in 28 body length-matched and 35 randomly-matched unique dyadic contests (126 total individuals). Behavioral theory states that body length-matched contests should be more escalated than randomly-matched contests. Therefore, we predicted that if sparring is a signal used in escalated contests, then body length-matched competitors should show a greater reliance on sparring than randomly-matched competitors. Sparring behaviors comprised 66% of all behaviors in body length-matched contests, compared to 38% of all behaviors in randomly-matched contests. Additionally, one sparring behavior (defensive telson coil) predicted the loser's retreat in both contest types. Given that sparring is more common in body length-matched contests that are predicted to be more highly escalated than randomly-matched contests, and that the defensive telson coil that occurs during sparring predicts a loser's retreat, we conclude that *N. bredini* use sparring as a signal during escalated contests and that this signal may resolve contests. Sparring integrates lethal weaponry with contest-resolving behavioral signaling, offering insights into the critical balance of intraspecific aggression and resolution.

P3.68 GREEN, R*; RAPPOPORT, R; YEAGER, D; CODDINGTON, E; Willamette U.; *rgreen@willamette.edu*
Examining the structure and function of brainstem neurons involved in sensorimotor processing of clasping behavior.
The brainstem of tetrapod vertebrates is essential for the generation, modulation, and maintenance of fundamental sensorimotor programs leading to basic behavioral repertoires such as locomotion, eating, and copulating. Early 20th century behavioral experiments by Sherrington and Kuypers independently revealed these brainstem functions in decerebrate cats and monkeys. However, little research has been done on this important brain region since. In an effort to understand how the brainstem neural circuits mediate behaviors, we are building a library of the structure and function of cells in the rostromedial reticular formation (mRF) of the medulla oblongata. Reticulospinal neurons in the mRF provide major descending input to the spinal cord mediating movements of all vertebrates, and we understand the mRF to be key in mediating the expression of clasping behavior by newts, Taricha granulosa. To grow an understanding of the mRF, we are using a combination of neurophysiology, imaging, modeling, and immunohistochemistry. The intrinsic properties of random mRF neurons are recorded using whole cell electrophysiology, the same neuron is then imaged using confocal microscopy, the 3D image combined with information about phenotype and physiology is processed in Fiji software, and cell models are generated in Neuron software. Neurotransmitter phenotype is identified using immunohistochemistry. The combination of these approaches creates an atlas of characteristics of mRF neurons, and will broaden our knowledge of how neuron shape, size, and neurotransmitter identity are related to the intrinsic properties of these mRF neurons. Given how conserved the function of the mRF is across all vertebrates, we anticipate that this knowledge will elucidate new principles in the organization and operation of the motor brainstem.

6.5 GREEN, B*; GOSLINER, TM; California Academy of Sciences; *bgreen@calacademy.org*
A preliminary molecular phylogeny of the nudibranch genus Flabellina
Flabellina is a large and morphologically diverse genus of aeolid nudibranchs. As a consequence of this diversity, the genus has been difficult to define through morphological study, and historically has repeatedly been subject to revision and redefinition. To date, no molecular phylogeny of the genus has been published. Using the molecular mitochondrial markers 16S and cytochrome oxidase subunit I (COI), and the nuclear markers H3 and 28S, we present a preliminary molecular phylogeny of *Flabellina*. We discuss how the evolutionary relationships revealed by this phylogeny reflect patterns of morphology and biogeography within the genus, as well as the evidence this study provides for the lack of monophyly within *Flabellina* and its parent family Flabellinidae.

1.4 GREEN II, DA*; DUAN, Y; KRONFORST, M; University of Chicago, Peking University; *dagreen2@uchicago.edu*
Investigating the Role of Insulin/IGF Signaling in Determining Migration Traits in the Monarch Butterfly
Insulin/insulin-like growth factor signaling (IIS) plays a major role in translating environmental condition to physiological and reproductive state. As well, IIS controls organismal growth and size in pre-adult stages. All of these traits are important differentiators of migrant and non-migrant monarch butterflies (*Danaus plexippus*). Here we investigate the role of IIS in determining migration traits in monarchs. We combine environmental switch experiments and targeted gene expression analyses of IIS pathway components. We find that multiple monarch insulin-like peptides (ILPs) show distinct profiles of dynamic expression throughout larval stages, suggesting that individual ILPs serve specific functional roles and potentially influence migratory trait development. We leverage natural variation in migratory ability to take a comparative approach to understand the molecular genetics and evolution of migration traits in monarchs.

125.6 GREENWAY, R.*; KELLEY, J. L.; TOBLER, T.; Kansas State University, Washington State University; *greenrs@ksu.edu*
OXPHOS adaptation and ecological speciation in toxic sulfide springs
Incompatibility between gene products encoded by mitochondrial and nuclear genomes (mitonuclear incompatibilities) is a mechanism of hybrid incompatibility hypothesized to serve as a major contributor to speciation. Oxidative phosphorylation (OXPHOS) consists of genes encoded by both genomes and is responsible for the fundamental process of aerobic ATP production. OXPHOS is a candidate for mitonuclear incompatibilities as hybridization between divergent populations or species can lead to the breakup of co-adapted mitonuclear gene products. Hydrogen sulfide (H_2S) rich habitats provide an ideal natural setting for testing hypotheses about mitonuclear incompatibility, as H_2S is extremely toxic to most organisms due to its inhibition of OXPHOS. H_2S toxicity results in direct selection on OXPHOS in habitats with high concentrations of H_2S. Despite strong selection, tolerance to high concentrations of environmental H_2S is known from multiple evolutionarily independent populations of fish in the family Poeciliidae. Direct selection on OXPHOS in sulfidic populations could lead to the coevolution of mitonuclear interacting proteins that do not function when combined with subunits originating from non-sulfidic populations, resulting in hybrid incompatibilities and contributing to ecological speciation. Using transcriptome data and protein structure modeling, we investigated signatures of positive selection and mitonuclear coevolution in the OXPHOS pathways of sulfidic populations. Analyses of molecular evolution consistently indicate relaxed selection on OXPHOS genes in sulfidic populations. Furthermore, some lineages of sulfide spring poeciliids show signatures of strong positive selection on OXPHOS genes as well as coevolution between mitochondrial and nuclear OXPHOS genes.

P1.105 GRESHAM, JD*; EARLEY, RL; University of Alabama, University of Alabama ; *jdgresham1@crimson.ua.edu*

Fitness Consequences of Self-Fertilization versus Outcrossing for the Mangrove Rivulus Fish

Mangrove rivulus fish (*Kryptolebias marmoratus*) exist predominantly as self-fertilizing hermaphrodites but males occur in varying abundances across their expansive geographical range. As follows, levels of outcrossing between hermaphrodites and males and heterozygosity also differ dramatically among populations, which raises the question of why males would be favored in some areas more than others. We hypothesized that heterozygous progeny derived from outcrossing would have higher fitness than homozygous offspring derived from selfing, especially under stressful environmental conditions. We predicted that more heterozygous fish would have lower mortality rates, higher growth rates, and greater reproductive success than homozygous fish, and that this fitness asymmetry would be amplified under suboptimal environmental conditions. To test this hypothesis, fish with varying levels of heterozygosity were exposed to control conditions and to high/low salinity and variable water availability, environmental stressors that characterize their native habitat. We report preliminary data on variation among genotypes in a number of fitness-related life history characteristics, including growth rate, fecundity, and offspring survival.

P3.156 GRIEGO, MS*; DESIMONE, J; GUTIERREZ RAMIREZ, M; GERSON, AR; UMass Amherst; *mgriego@umass.edu*

Aminopeptidase-N Modulation Assists Lean Mass Anabolism during Refueling in the White-throated sparrow (Zonotrichia albicollis)

Birds catabolize protein along with energy- dense lipids to meet the intensive metabolic demands of migration which leads to significant organ atrophy in small songbirds. Consequential reductions in gastrointestinal tissue- as great as 50%- initially constrain refueling rate during stopover, yet birds are able to regain digestive performance within a short period of time. To aid in the rebuilding of lean tissues after flight, birds must maintain the ability to digest and assimilate protein, despite reduced intestine mass. Aminopeptidase-N (APN) is a brush-border enzyme responsible for cleaving amino acids from peptides and is necessary during the final stage of protein digestion and absorption. The aim of this study was to determine if migratory passerines dynamically regulate APN to prioritize the assimilation of protein during simulated migration and stopover. We hypothesized birds recovering from a fast would upregulate APN activity to quickly process and integrate dietary protein into lean mass. We fasted 25 wild-caught migratory white-throated sparrows (*Zonotrichia albicollis*) for 48h to mimic fat and lean mass reductions experienced during flight, and measured intestinal APN activity before the fast, after the fast, 24 hours post fast, and 48 hours post fast. Total fat mass, lean mass, and basal metabolic rate (BMR) were measured daily. Our data reveals that fasted birds maintain APN activity through the fast, despite a 30% reduction in intestine mass, and during refueling birds increase APN activity nearly two-fold over pre-fasted individuals. This suggests that APN is preferentially maintained during fasting and dynamically up-regulated to meet the increased protein demand during migratory stopover.

P3.120 GRIFFIN, M/T*; NOVARRO, A; Univ. of Maryland, College Park; *mgriff13@terpmail.umd.edu*

Ecological impacts of climate change: examining the limiting roles of rainfall and intraspecific competition on red-backed salamander foraging success.

As climate change and sea ice melt continue to progress, associative tidal and atmospheric patterns will increase the probability of extreme weather events, including drought and heat wave, at mid latitudes. The physiology of lungless terrestrial salamanders, in the genus Plethodon, makes them extremely sensitive to fluctuations in moisture availability; while their high abundance, small territory size, and ecological role as midlevel vertebrate predators make them excellent indicators of biodiversity, ecosystem integrity, and long term forest health. In this study we investigated the effect of drought and consequential intraspecific competition on the foraging success of P. cinereus, a species of Plethodon native to eastern North American forests. To investigate how the frequency of rain events influences salamander survivorship, we examined the density dependent relationship between moisture and individual foraging success (percent change in mass). To do so we manipulated soil moisture and population density under quasi-natural conditions in a lab based ecological experiment. Salamanders were randomly assigned to enclosures of different soil moisture and population density for each trial, and fluorescently tagged for identification. Trials consisted of a week-long acclimation period, leading up to a 48-hour period of competition following a feeding event. We predicted that foraging success is positively related to total rainfall. Moisture mediated pulses of food availability and intraspecific competition will compound this effect, so that salamanders exposed to dry conditions and high densities will exhibit the lowest fitness. By identifying the effect of prolonged drought in natural salamander populations our results will contribute to the ecogeography of eastern North American forests in the face of global climate change.

1.3 GRIFFITH, OW*; CHAVAN, A; PROTOPAPAS, S; MAZIARZ, J; WAGNER, GP; Yale University; *oliver.griffith@yale.edu*

The Evolutionary Origin of Implantation in Mammals: an Examination of Maternal-Fetal Interactions in the Short Tailed Opossum

The evolution of live birth in vertebrates requires the formation of a placenta, which is an organ formed by the apposition of maternal and embryonic tissues to support the exchange of materials between mother and embryos during pregnancy. Whilst the first mammals were egg laying, live birth evolved in the common ancestor of marsupial and eutherian mammals approximately 170 mya. In this common ancestor pregnancy is believed to have been short, with mothers giving birth to small, under-developed young. This mode of reproduction has been retained in marsupial mammals. To understand the genetic processes that support the formation of the placenta in marsupials we measured transcriptome wide gene expression in uterine tissues of non-, mid-, and late-pregnant grey short-tailed opossums (*Monodelphis domestica*). On this data we performed differential gene expression and gene ontology analysis. We found that during late gestation there was a significant over representation of genes involved in inflammation, which is an important component of the implantation pathway of eutherians. We also identified several key genes involved in eutherian implantation that were highly expressed in late pregnant uterine tissue. Using immunohistochemistry we show that these changes occur in the uterine epithelium, and hence at the maternal-fetal interface. Together our data suggest that the late gestation phase of pregnancy in opossums is homologous to the implantation phase of pregnancy in eutherian mammals. Further, we suggest that the processes that facilitate implantation in eutherians, may have had fundamentally different roles when they were co-opted to pregnancy in early viviparous mammals.

P1.104 GRIFFITHS, JS*; KELLY, MW; HELLBERG, ME; Louisiana State University; *joanna.griffiths4@gmail.com*

Investigating Latitudinal Shifts in Allele Frequencies Over 20 Years in the Coral Balanophyllia elegans

Local adaptation to upwelling systems is a potential mechanism for resilience to future ocean change. Upwelling brings acidic water to the surface, but many species have been found to survive low pH values despite its corrosive effects. *Balanophyllia elegans* endures heterogeneous environments both through its broad geographic range (Southeast Alaska to Baja California) and the seasonal variability in temperature and upwelling throughout the year. This wide range of selective pressures and *B. elegans'* restricted larval dispersal may promote high population structure and local adaptation. Hellberg (1994) discovered allozyme clines in *B. elegans* that correlate with latitude although differences among localities were not significantly different. Using a whole-genome scan (RADSeq), we will reanalyze historical coral samples from four of the same locations in California collected by Hellberg (1994) and compare them to modern samples from the same sites. We will compare the frequency and number of alleles between populations and with time. We expect to observe changes in allele frequencies that shift with environmental gradients in temperature and upwelling through space and time. For example, there might be a shift in allele frequency to favor alleles that are warm adapted, causing Northern populations to shift towards allele frequencies historically found in Southern populations.

38.6 GRIFFITHS, JS*; KELLY, MW; HELLBERG, ME; Louisiana State University; *joanna.griffiths4@gmail.com*

Intraspecific Variation in the Response of the Coral, Balanophyllia elegans, to Future Ocean Acidification

Predicting the response of marine species to future ocean acidification (OA) is key to anticipating future ecological impacts of ocean change. However, forecasting ecosystem changes is difficult due to variation among species and individuals in their response to this stressor. Many OA studies extrapolate the response of one population to the entire species, but a single population may not be representative if the species spans a heterogeneous geographic range. This study compares the response of two populations of the coral, *Balanophyllia elegans* from California, to future OA conditions. These two populations experience distinct upwelling regimes, which bring acidified water to the surface. To endure upwelling, populations of *B. elegans* must be plastic to fluctuating pH, but the lower limits of their pH tolerance may differ according to their environment's upwelling regime. We measured gene expression and respiration rates in corals from both populations exposed to $p\mathrm{CO}_2$ levels of 750 and 2000 µatm for four weeks. Corals from the northern population, which experience lower pH in their natural habitat, maintained the same respiration rate throughout the exposure, suggesting resilience to future pH levels. In contrast, corals from the southern population showed an increase in respiration rate throughout the exposure to low pH, suggesting an increased metabolic demand. Higher tolerance to low pH conditions in *B. elegans'* northern range may provide an evolutionary step towards maintaining important processes of high metabolic demand in the face of future OA. Using RNASeq data collected at three time points (day 0, 9, and 29) we will compare changes in gene expression throughout the exposure and between populations, thus identifying genomic mechanisms of resilience to future OA.

143.1 GRIMES, C.J.; Texas A and M at Galveston, Galveston, Texas; *CG1478@tamu.edu*

Ecological Baseline of Macroinfaunal Assemblages in Nearshore Sediments of Southeast Florida

Alterations to coastal ecosystems require researchers to formulate ecological baselines for comparison studies to identify the effects, if any, to nearshore communities. As the Florida coast is tested with beach replenishment, sea level change, global warming, and human population growth, establishing and monitoring baselines will allow effects of alterations to be elucidated. Hence, benthic cores collected quarterly from locations along Florida's southeastern coast from May 2015 to February 2016 using a 7.7-cm PVC corer to examine macroinfaunal abundance, composition, and diversity, as well as sediment characteristics (e.g., composition and sphericity). The results suggest median grain size is negatively correlated with infaunal abundance, diversity, and species richness, and an increase in species diversity indices and infaunal abundance as distance to the Equator decreases. The middle sites of the study, located closer to the Florida Current, tended to contain higher percentages of carbonate and median grain size than the southernmost and northernmost sites. Polychaetous annelids (mainly *Armandia agilis* and *Paraonis fulgens*), mysid shrimp (*Chlamydopleon dissimile*), isopods (*Euryidice piperata* and *Ancinus depressus*), and amphipods (*Bathyporeia parkeri*) dominated a majority of the sites across all months. This study supports the idea of resilient infaunal communities as the results suggest no long term effects with regards to temporal proximity of beach replenishments. The results of this study provide a baseline for macroinfaunal composition and sediment characters for future studies along Florida's southeastern coast.

50.4 GROOM, DJE; TOLEDO, MCB; POWERS, DR; TOBALSKE, BW; WELCH, KC*; WELCH, Kennet; University of Toronto Scarborough, University of Taubate, George Fox University, University of Montanna; *kwelch@utsc.utoronto.ca*

The scaling of mechanochemical efficiency of hovering hummingbirds

High elevations are characterized by reductions in environmental parameters, such as oxygen availability and air density, which can affect flight performance. Typically, larger hummingbirds tend to be overrepresented at high elevation and their predominance there has been attributed to having disproportionately larger wings relative to lowland populations. The larger wings may offset the increased energetic requirements for flight at high elevation and affect how hovering metabolic rates scales with mass, morphology, and kinematics amongst taxa found at different elevational ranges. Based on the relationship between wing size and elevation, it is hypothesized that hovering metabolic rate would decline with increasing wing area and length, after accounting for body mass effects on both parameters. Oxygen consumption rates were recorded from hummingbirds using open-flow mask respirometry. Combining this with literature values, we examined the scaling of metabolic rates, wingbeat frequencies, and wing morphologies of hummingbird species across a 2200m gradient. We did not find a relationship between wing area and elevation, and found no scaling relationship between hovering metabolic rate and any morphological variables or kinematics after controlling for body mass. Overall, there is no evidence of adaptation of wing morphology to reduce energetic demands. Instead, high elevation performance may be related to their mechanochemical efficiency. Combining measurements of mechanical power output with the oxygen consumption data, efficiency displays positive scaling with body mass. The efficiency of the flight muscles may play a larger role in determining the upper elevational limits, as the more oxygen efficient muscles may provide greater aerobic scope at high elevations.

P1.65 GUELL, BA*; KURLE, CM; ZEPPELIN, TK; REAM, RR; Univ. of California, San Diego, NOAA/NMFS/MML, NOAA/NMFS/MML; *bguell@ucsd.edu*

Determining northern fur seal pup weaning with stable isotope and stomach content analyses

Mammals undergo major dietary changes upon weaning, however their life histories can make it difficult to observe foraging behaviors in nature. Northern fur seals (*Callorhinus ursinus*; NFS) are primarily in the Bering Sea and North Pacific Ocean, and roughly half the world's population breeds on the Pribilof Islands, Alaska. Pups are born in July, nurse intermittently for ~4 months, then wean and depart the island for an extended pelagic migration. The often cryptic, pelagic foraging of NFS makes them ideal candidates for stable isotope analysis (SIA) which has been used to describe the foraging behaviors and habitat use of adults and juveniles. Because pups rely on their mother's milk before weaning, we assumed their stable isotope values would reflect a higher trophic level than that of their mothers throughout their nursing period. When pups begin consuming a likely diet of small fish and crustaceans, we expected to see lower stable nitrogen isotope values ($\delta^{15}N$) in pup tissues. The degree to which pups forage for prey to supplement milk consumption, however, or whether they abruptly switch when the migration begins, is unknown. To estimate this shift, we collected milk and prey contents from stomachs, vibrissae, muscle, liver, and serum samples from pups taken during subsistence harvests on St. George Island, Alaska, throughout the nursing period (Sept, n=5; Oct, n=31; Nov, n=21). NFS vibrissae grow throughout their lifetimes, so they provide a continuous record of assimilated diet. SIA of vibrissae segments allowed for a chronological measure of pup diet from in-utero to weaning, whereas SI values from liver and serum provided assimilated diet data from the week previous to sample collection. We compared stable isotope values from pup tissues to those from NFS milk and other prey collected from their stomachs to determine how well SIA captures the weaning process.

S2.4 GUGLIELMO, Christopher/G.; Western University; *cguglie2@uwo.ca*

The challenge and promise of integrating wind tunnel and field studies of endurance of flight migratory birds

Migrating birds can sustain the high rate of energy expenditure required for flight for as long as a week or more without supplemental food or water. Mortality during migration can be high, and so understanding the extrinsic and intrinsic factors that influence individual endurance flight performance is crucial to understanding the evolution of migration. I will review what has been learned from wind tunnel studies about the energetics and physiology of bird flight and describe how new ground and space-based tracking should be used to field test what is learned from captive birds. I will discuss the effects of factors like diet, disease status, high altitude, humidity, and environmental contaminants on flight performance, and illustrate how conditions have never been better to study bird migration physiology in the lab and field.

P2.58 GUIFFRE, CM*; DOUGLAS, DC; HULBERT, AC; MITCHELL, TS; HALL, JM; WARNER, DA; Auburn University; *cmg0052@auburn.edu*

Noninvasive heart rate detection of Anolis sagrei embryos using a digital egg monitoring system

Heart rate is an informative physiological trait that is measured in many studies because it can be an index of the workload of the cardiovascular system as it transports gasses, nutrients, and hormones throughout the body. Detecting changes in heart rate can allow researchers to study the effects of variable conditions during embryonic development. Measuring the heart rates of developing embryos, however, is logistically more challenging than measurements in adult organisms. The Buddy® system is a digital egg monitor that detects heart rates without affecting embryogenesis. The Buddy® utilizes infrared light to noninvasively measure embryonic heart rates, and though originally designed for bird embryos, this device has also been useful in detecting heart rates of non-avian reptile embryos. Currently, it has primarily been used on species that lay relatively large eggs, such as turtles and iguanas. In this study, we evaluated the effectiveness of the Buddy® system at measuring heart rates of embryos in a lizard species that produces very small eggs (~0.1 g), the brown anole (*Anolis sagrei*). Eggs from captive anoles were incubated under fluctuating incubation temperatures, mimicking a natural, daily temperature regime. We utilized the Buddy® system to examine how heart rates change both throughout a daily temperature cycle and throughout embryonic development. Preliminary results suggest heart rates are positively correlated with daily temperature fluctuations, but not age of the embryo. While the Buddy® was effective at measuring heart rates of *A. sagrei*, we outline several limitations to its utility for measuring heart rates of small eggs. Despite these limitations, we present the first baseline measures of anole heart rates and recommend the Buddy® system as a tool to further expand the utility of anoles as model systems in evolution, ecology, and physiology.

P2.188 GUIGUENO, M.F.*; KAROUNA-RENIER, N.K.; HENRY, P.F.P; HEAD, J.A.; PETERS, L.E.; PALACE, V.P.; LETCHER, R.J.; FERNIE, K.J.; Department of Natural Resource Sciences, McGill University, Patuxent Wildlife Research Center, United States Geological Survey , Stantec Consultants, International Institute for Sustainable Development - Experimental Lakes Area, Environment and Climate Change Canada; *melanie.guigueno@mcgill.ca*

Identifying adverse effects on neuroanatomy of hatchling American kestrels exposed to two novel brominated flame retardants

Each year, new chemicals are introduced to the market, including flame retardants. Techniques for assessing these chemicals for risk assessment have generally not considered their potential impacts on the brain. Some flame retardants accumulate in the brain, and the brain is known to be sensitive to physiological perturbations including contamination. We used an established technique, neuroanatomy, in a novel context, ecotoxicology. We exposed American kestrels (*Falco sparverius*), key top predators of terrestrial ecosystems, in ovo to one of two commonly used brominated flame retardants (BFRs): 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (EHTBB), or bis(2-ethylhexyl)-2,3,4,5-tetrabromophthalate (TBPH). We measured the volumes of the hippocampus and the telencephalon in the left and right hemispheres to determine whether hippocampus volume relative to the telencephalon and symmetry between hemispheres were affected by BFR exposure. The hippocampus, a region in the telencephalon, plays a crucial role in spatial memory and navigation in birds. BFRs are especially likely to impact the hippocampus because of their known effects on thyroid hormones that influence hippocampus development and neurogenesis, and on sex steroids for which the avian hippocampus expresses androgen and estrogen receptors. Changes in neuroanatomy could have an impact on behaviour at the individual level, and ultimately, affect populations.

34.7 GUINDRE-PARKER, S.*; RUBENSTEIN, D.R.; Columbia University; *slg2154@columbia.edu*

Cooperative breeding reduces the oxidative costs of reproduction

All sexually reproducing organisms are faced with a fundamental decision: to invest valuable resources and energy in reproduction or in their own survival. This trade-off represents the ‘cost of reproduction' and is thought to underlie a number of behavioral adaptations, including the evolution of mating systems. However, the hypothesis that costly parental care favors the evolution of cooperative breeding has not been formally tested because until recently we lacked an understanding of the mechanism that shaped the costs of reproduction. Oxidative stress—the imbalance between harmful reactive oxygen species and neutralizing antioxidants—has been demonstrated to link current reproductive effort to future survival across taxa. We test whether breeding cooperatively reduces the oxidative costs of reproduction in two sympatric species of African starlings that differ in their mating system. We show that individuals of the non-cooperative species incurred an oxidative cost of reproduction, whereas this costs was reduced in individuals of the cooperatively breeding species. These oxidative costs were not related to individuals' investment in nest guarding or offspring provisioning, but increased with a general index of breeding workload (number of chicks * age of chicks). Furthermore, oxidative costs were lowered in individuals of the cooperatively breeding species because the breeding workload was shared among numerous individuals, yielding a lower per capita workload than in non-cooperative individuals. This research represents a unique comparison across two sympatric species of birds demonstrating that cooperative breeding does reduce the oxidative costs of reproduction. As such, our work supports the theory that the costs of reproduction play a role in shaping the evolution or maintenance of mating systems.

46.4 GUMM, JM*; CARLETON, KL; MENDELSON, TC; Stephen F. Austin State University, University of Maryland, College Park, University of Maryland, Baltimore County; *gummj@sfasu.edu*

Genetic mechanisms underlying variation in visual systems of freshwater fishes in the genus Etheostoma

Variation in visual systems may lead to differences in visually mediated behaviors. In fishes, visual sensitivity is correlated with behaviors such as female mate preferences. In darters (genus Etheostoma), males express elaborate breeding coloration and female preferences are based on male coloration. Darters are dichromatic with photoreceptors sensitive to medium and long wavelengths of light. The wavelength of peak sensitivity in both photoreceptor types varies both among and within species. Visual sensitivity is determined predominantly by visual pigments composed of an opsin protein bound to a light-sensitive chromophore. Proximately, at least two molecular mechanisms underlie variation in visual sensitivity: 1) Structural changes, wherein sequence differences in the coding regions of opsin proteins alter the types and spectral characteristics of the visual pigment and 2) differential gene expression, which alters spectral sensitivity through regulation of opsin genes. We tested whether variation in darter visual sensitivity is due to differences in gene sequence, gene expression, or both. Sequencing the opsins in 25 species of darters, we found variation in spectral tuning sites among species. Structural changes in the medium wavelength sensitive opsin appear to contribute most to the measured variation in visual sensitivity. Additionally, qPCR methods assessing relative levels of gene expression of opsins suggest that regulatory changes also contribute to the diversity of visual systems in darters. By linking visual physiology and genetic mechanisms within and among species, our results help elucidate the relative contributions of structural and regulatory changes during the diversification of visual systems.

S1.4 GUNDERSON, A.R.*; KING, E.; BOYER, K.; TSUKIMURA, B.; STILLMAN, J.H.; San Francisco State, UC Berkeley, Cal State Monterrey Bay, Cal State Fresno; *alexrgunderson@gmail.com*

Species interactions and the cellular stress response in an intertidal crustacean system

Global change is predicted to increase the physiological stress of many organisms. At the cellular level, nearly all organisms respond to stress by upregulating a highly conserved set of genes in what is known as the cellular stress response (CSR). Though induction of the CSR is typically associated with variation in abiotic stress, there is increasing evidence that stress associated with biotic interactions, such as predation risk and competition, can also induce the CSR. This has many potential implications, including the possibility that biotic and abiotic stress can produce physiologically synergistic negative effects under global change. We investigated species interactions and the CSR using a pair of sympatric, congeneric intertidal crabs: *Petrolisthes cinctipes* and *P. manimaculis*. Warming is predicted to cause an increase in the distributional overlap of these species at a microhabitat level. We conducted controlled laboratory experiments in which focal crabs were housed with either conspecifics or heterospecifics. We quantified the number of agonistic interactions focal individuals experienced, and subsequently measured the expression of a number of Heat Shock Proteins (hsps) associated with the CSR. We found that crabs engaged in significantly more agonistic interactions with heterospecifics than with conspecifics; however, there was no difference in hsp expression for crabs with heterospecifics vs. conspecifics. In addition, the number of agonistic interactions an animal experienced did not correlate with hsp expression. This suggests that induction of the CSR may not be a general feature of competitive interactions. Our future work will replicate these experiments under varying density regimes, as we have found evidence that hsp expression is enhanced at high densities in single-species groups.

9.7 GUNDLACH, KA*; WATSON, GM; University of Louisiana at Lafayette; *kag9159@louisiana.edu*

Interspecific Anemone Mucus Enhances Cnida Discharge in the Anemone, Haliplanella luciae

The distinction between self and non-self is important for all animals. Certain species of sea anemone live in tightly packed communities, among clonemates and non-clonemates. Competition for space leads to intraspecific and interspecific aggressive interactions among anemones. The initial aggressive interactions appear to involve reciprocal discharge of cnidae triggered by contact with non-self feeding tentacles. In this study, we found that anemone mucus sensitizes cnida discharge. Interspecific mucus significantly enhances nematocyst discharge twofold and spirocyst discharge fourfold relative to baseline values obtained in seawater alone. Conspecific mucus does not enhance cnida discharge relative to baseline values. These data suggest that anemone mucus contains one or more components that specifically are involved in self, non-self recognition as related to cnida discharge. Hence, cnidae in feeding tentacles are employed as weapons among anemones engaged in aggressive interactions. Recognition of non-self begins before the anemones move into direct contact with each other. Surprisingly, the disproportionately larger enhancement of spirocyst discharge as compared to nematocyst discharge suggests that spirocysts may be an effective weapon among anemones despite the commonly held view that spirocysts are most effective when discharged onto hard substrates.

P1.40 GUNN, T*; BEDORE, C; Georgia Southern University; *tg03328@georgiasouthern.edu*

Environmental Regulation of Yellow Stingray Camouflage

Many reef fishes exhibit dynamic coloration and body patterns that can change under nervous control. Lowe et al (1996) showed that hammerheads in high UV environments have higher skin melanin concentrations, which likely functions as a protective mechanism against UV damage. However, several species of benthic sharks and rays likely alter melanin concentrations in the skin to provide background matching for camouflage. The yellow stingray (Urobatis jamaicensis) is a small, reef-dwelling elasmobranch with elaborate spot patterns that provides effective camouflage against their rock-reef background. Because yellow stingrays likely use this camouflage as a predator avoidance strategy, melanin responses to UV light may be supplemented by responses to other environmental mechanisms such as habitat color/brightness. To investigate this hypothesis, we housed rays in either black or white tanks for one week. Stingrays in black tanks darkened their skin approximately 96%, whereas rays in white tanks lightened their skin color an average of 142%. When moved to the opposite color, all rays either darkened or lightened according to their new tank. To investigate the role of UV light on changes in camouflage, rays were housed individually in black and white tanks and were held in either 24h light (UV present) or 24h dark (UV absent). Preliminary results indicate that rays adjust to their tank conditions independent of the presence of UV; rays in both 24h light and 24h dark treatments darkened or lightened according to their tank color within the 3-day test period. We plan to further examine the underlying physiological mechanisms that control color change in the yellow stingray, including the extent to which color change is visually mediated.

P1.130 HACK, N*; STROBEL, JS; BECKMAN, BR; LEMA, SC; Cal Poly San Luis Obispo, NOAA Northwest Fisheries Science Center ; *niccihack@gmail.com*

Insulin-like Growth Factor I (IGF-I) as a Physiological Biomarker for Growth Rate in Juvenile Sebastes Rockfishes

Currently, commonly used methods for quantifying individual growth rates of wild fishes require terminal sampling (otolith analysis), time consuming tagging (mark-recapture), or have limited value as indicators of somatic growth (RNA:DNA ratios). The development of rapid, non-lethal methods for quantifying growth rates is needed to provide data necessary for informed fisheries management. Blood hormone concentrations have shown to be accessible indicators of growth regulation and metabolism. Specifically, insulin like growth factor-I (IGF-I) has a low clearance rate and robust relationship to somatic growth in several fishes, making it a potential endocrine biomarker of specific growth rate for fisheries applications. Here, we tested whether plasma IGF-I concentrations could be used as a tractable indicator of somatic growth and nutritional status in *Sebastes* rockfishes, a group of species important to commercial and recreational fisheries on the Pacific coast of N. America. To test associations between IGF-I and growth rate, we collected juvenile olive rockfish (*Sebastes serranoides*) and yellowtail rockfish (*Sebastes flavidus*) from central California, USA, and reared them in captivity under food ration treatments of 1% or 4% wet mass per day to experimentally generate growth variation. We hypothesize that fish raised under higher rations will exhibit high plasma total IGF-I concentrations. We also hypothesize that hepatic mRNA levels for IGF-I (*igf1*) and IGF binding protein-1b (*igfbp1b*) will be elevated in rockfish exhibiting faster somatic growth. Linking concentrations of IGF-I to growth and nutritional status in rockfish could provide a non-terminal assessment of health for these over-harvested species.

P2.187 HAGEN, A.; ZOU, E.*; Nicholls State University; *em.zou@nicholls.edu*

Triclosan stimulates the activity of the molting enzyme N-acetyl-beta-glucosaminidase in the epidermis of the fiddler crab, Uca pugilator

Triclosan (TCS), an antimicrobial agent frequently found in aquatic environments, has recently been shown to inhibit crustacean molting. The present investigation sought to understand whether the molt-disrupting effect of TCS arises from disruption of molting hormone signaling. Because of the structural resemblance of TCS to polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) capable of disrupting molting hormone signaling, it was hypothesized that TCS would also act through disrupting molting hormone signaling in Crustacea. Exposure of fiddler crabs, *Uca pugilator*, to TCS at 10 - 250 µg/L for six days had no effect on activity of epidermal N-acetyl-beta-glucosaminidase (NAG), also known as chitobiase, a biomarker for molting hormone signaling. However, TCS at 2500 µg/L significantly increased enzymatic activity, suggesting that TCS at this environmentally unrealistic concentration is capable of enhancing ecdysteroid signaling in vivo. The underlying mechanism for this stimulating effect on epidermal NAG activity needs to be investigated.

114.2 HAGEY, T/J; Michigan State University; *hageyt@msu.edu*

Convergence in Gecko Toe Pad Shape

Geckos are well known lizards for their striking climbing and clinging abilities. The adhesive toe pads of gecko lizards come in a while variety of shapes and sizes. Anecdotally, species have been lumped into toe pad type-classes, irrespective of phylogenetic relationships. Using geometric morphometrics, we asked if distantly related species of geckos are morphologically convergent. We found that morphologically similar species do clump in PC morphospace. With the addition of a phylogeny, we also found repeated evolution of similar morphologies across distant species.

P1.74 HAJDUK, MM*; SCHULZE, A; Texas A&M University at Galveston; *mmhajduk@tamu.edu*

Using Metabarcoding Approaches to Assess Meiofaunal Communities of the Laurentian Great Lakes

In aquatic ecosystems, meiofaunal organisms (~40-500 µm in size) are known to influence their local environment through nutrient uptake and cycling and burrowing and feeding behaviors. In addition, dominant meiofaunal organisms, such as copepods and nematodes, are used as food resources for native and invasive fauna. In the Laurentian Great Lakes, meiofauna communities have been linked to invasive round goby populations (as a food resource), and increased meiofaunal abundance has been linked to waste produced by non-native zebra and quagga mussels. Efforts have been made since the 1980s to observe and quantify meiofaunal communities in specific areas of the Great Lakes; however these studies were limited in size of geographic area, number of samples, and the number of lakes sampled. For the current study, meiofaunal samples have been collected across all five of the Laurentian Great Lakes in order to examine community composition and diversity through the use of metabarcoding, which makes use of operational taxonomic units (OTU), which are matched to faunal phyla or classes. This process will provide an overview of community structure and percent contribution of meiofaunal groups to the community by sites, various depths, and whole lakes. Community structure will be tested for differences between lakes, as well as differences in structure over time using historical data. Additionally, differences in community structure between an individual lake's basins will be evaluated.

S8.7 HALE, M. E. *; HENDERSON, K. W. ; Univ. of Chicago; *mhale@uchicago.edu*

Swimming kinematics and performance through early life history of fishes

Swimming is a key component of many fundamental behaviors of fishes, including predator escape and prey capture. Research on swimming kinematics and performance has focused on the adult stage; however, swimming and associated behaviors are critical for survival throughout post-hatching ontogeny. High performance of some kinematic parameters may be particularly important at earlier life history stages as differences in size and maturation, and associated fluid dynamics may require alternative movement strategies. A distinctive time in the ontogeny of fishes is the transition from dependence on yolk sac nutrients to exogenous feeding. Exogenous feeding necessitates increased search and capture swimming, increased predation risks, and possibly greater need for high performance escape. A second transition that occurs during post-hatching ontogeny of many species is a switch from cutaneous to gill-based respiration, which fundamentally changes behavioral functions of the pectoral fins. As the need to use fin beats for fluid mixing and respiration ends, the pectoral fins become incorporated into locomotor behaviors and fin morphology and movements change. Here we discuss swimming and its morphological and physiological underpinnings across feeding and respiratory transitions with a focus on performance change through life history. A key, often overlooked, factor in swim performance is the neural control of movement, which includes both motor output and sensory modulation. During early life history both motor and sensory systems change dramatically, but not necessarily in lockstep. Understanding how the early organization and development of these systems impact movement provides key insight for interpreting kinematic patterns and performance differences across organisms.

116.7 HALL, JM*; WARNER, DA; Auburn University; *jmh0131@auburn.edu*

Thermal Spikes Caused by the Urban Heat Island Effect Result in Differential Egg Survival of a Non-native Lizard (Anolis cristatellus)

Embryonic development in ectotherms is very sensitive to abiotic nest conditions. In reptiles, high incubation temperatures often result in relatively short incubation periods and large hatching size, but extremely high temperatures can result in cardiac arrest and death. Human altered habitats, which potentially create novel thermal conditions in the soil due to the urban heat island effect, may therefore create new selection pressures for developing embryos. The urban heat island effect can increase temperatures in cities as much as 12° C, and our preliminary data suggests that soil temperatures differ markedly between urban and natural areas in locations where reptiles deposit eggs. We measured the temperatures of potential nest sites of the Puerto Rican Crested Anole (*Anolis cristatellus*) in both urban and natural areas of Miami-Dade county where this lizard and several other anole species are naturalized. We bred crested anoles in the lab and subjected their eggs to 5 incubation treatments that mimic potential temperature regimes from our field data, three of which included a thermal spike 1/4 of the way through embryonic development. Preliminary results suggest that thermal spikes increase metabolism and reduce egg survival and that each are a function of the magnitude of the spike. These results suggest that urban environments create novel selection pressures that potentially result in embryonic adaptation to novel temperature regimes or in novel nest-site selection strategies by females.

P1.281 HALL, MR*; BERG, O; MÜLLER, U; California State University, Fresno; *maxwellhall@mail.fresnostate.edu*

Trap size and age affect capture success in the carnivorous plant Utricularia vulgaris

Bladderwort *Utricularia vulgaris* is an aquatic carnivorous plant that catches zooplankton in small underwater traps. The trapping mechanism is active: when prey touches the trigger hairs on the trap door, it is sucked into the trap. Active mechanisms are energetically costly, hence we predict that the traps have a high capture efficiency (captures per feeding strike). Bladderwort is a rootless, free-floating primary stolon with a growing and a senescing end. In this study we explore the effects of trap size and trap age on capture efficiency. We fed the plant ostracods to study capture success as a function of trap diameter and age. We recorded capture events acoustically (traps make a popping sound when triggered) to characterize the time course and to calculate capture efficiency as the ratio of capture success (total number of prey items captured) to suction events (number of events in the sound recording). We found that capture behavior can be modelled as a first-order reaction with prey density declining exponentially over time. Traps mature within 10 days. Capture success is steady at 30 to 40% for mature traps and then gradually declines to zero as a traps senesce. Presented with ostracod prey (300 to 600 micron diameter), traps smaller than 1.3 mm were unable to catch prey. Overall, our results show that bladderwort are effective suction feeders with success rates (ratio of successful versus total number of strikes) higher than those of fish larvae with a similar gape size (e.g. *Sparus aurata* at age 6 days: gape 200 microns, capture success: 20%).

26.1 HALL, GJ*; DEAN, MN; PORTER, MM; Clemson University, Max Planck Institute of Colloids and Interfaces;
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Mechanical Behavior of a Biomimetic Chondrichthyan Feeding Mechanism: Influence of Dentition Patterns

Despite the relative compliance of cartilage compared to bone, many cartilaginous fishes (sharks, skates, rays, and relatives) are capable of thriving at a variety of extremes, including: living in high pressure environments, supporting massive body weights and muscular loads, or feeding on hard-bodied prey. Although there is extensive literature on shark feeding mechanics, cranial anatomy and tooth structure and function, questions still surround the structural foundation of the chondrichthyan feeding mechanism, namely the integrated functioning of its components: the cartilaginous jaw, with its mineralized and non-mineralized regions, the dental ligaments and teeth. Consequently, the efficacy of shark jaws to withstand loads, resist fracture and effectively transmit biting forces is a topic of interest among biologists, engineers, and material scientists alike. By applying geometric morphometrics principles, three-dimensional renderings of a jaw representative of a bonnethead shark (*Sphyrna tiburo*) were developed from 3D-laser scans, then remodeled into two tooth file patterns: a natural staggered pattern and a parallel one. Biomimetic prototypes were developed through additive manufacturing and tested in bending and compression to investigate the structural significance of tooth-jaw interactions created by the different dentition patterns. Preliminary results suggest that the staggered dentition patterns may increase the toughness of the biomimetic structures, a natural mechanical advantage that could be related to the feeding behavior of sharks.

P2.66 HALL, C*; RODRIGUEZ, M; WEI, A; WICTOR, E; GAZI, A; GARCIA, J; GENTILE, G; RIVERA, A; HILL, A; Univ. of Richmond, Richmond, Univ. of Pacific, Stockton, Univ. of Pacific, Stockton; *ahill2@richmond.edu*

Secreted frizzled related protein is a putative downstream target of PaxB in the freshwater sponge, Ephydatia muelleri

The Wnt Signaling pathway and the Pax/Six gene network both play important roles in establishing the sponge body plan and aquiferous system. Using computational approaches to identify transcription factor binding motifs in sponge genomes, we located putative PaxB binding sites upstream of a Secreted Frizzled Related Protein (SFRP) gene in *Ephydatia muelleri*. The EmSFRP contains a Frizzled domain with predicted glycosylation site as well as a Netrin domain. EmSFRP is expressed throughout development, but with highest levels in juvenile sponges. Knockdown of EmPaxB expression by RNAi results in decreased expression of EmSFRP, supporting that PaxB directly or indirectly regulates SFRP in sponges. Interestingly, knockdown of EmSFRP using dsRNA leads to ectopic oscula formation during development, as has been reported when GSK3 is inhibited by LiCl in this species. This data supports a hypothesis that EmSFRP may act as an antagonist of Wnt signaling in E. muelleri and that the regulation of the Wnt pathway by the Pax/Six network may have been established before sponges diverged from the rest of the metazoans.

P2.48 HALL, HR*; KAHRL, AF; JOHNSON, MA; Trinity University, San Antonio, University of Virginia, Charlottesville;
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Sexual Selection in Anolis Lizards: An Analysis of Sperm and Testis Morphology

Sexual selection acts on an organism's ability to successfully obtain mates, either through intersexual selection, generally via female choice of males, or intrasexual selection, where males compete against each other for access to females. Male competition for mates can occur both before and after copulation, but the relationship between these two types of competition is unclear. Stronger pre-copulatory male competition generally leads to greater sexual size dimorphism (SSD), with males growing to larger body sizes than females, while the strength of post-copulatory selection is often associated with testis and sperm morphology. To better understand the dynamics between these pressures when they are *both* present within the same individuals, we examined nine species of *Anolis* lizards from the Dominican Republic. Using cryosectioned testis tissues, we measured the cross-sectional area of the testis and the seminiferous tubules to assess the relationship between these measures with SSD and the gonadosomatic index (GSI, the ratio of testis mass to body mass). Our findings show that bigger lizards have bigger testes ($R^2 = 0.60$; $p = 0.005$) and that bigger testes have larger seminiferous tubules, regardless of body size ($p = 0.005$). Additionally, we found preliminary evidence suggesting that lizards with greater SSD have a smaller GSI ($R^2 = 0.238$, $p = 0.104$), indicating a tradeoff between the resources allocated to pre- and post-copulatory selection. To better understand how sexual selection influences the evolution of reproductive morphologies in lizards, we will include additional measures of testis morphology (lumen area, seminiferous epithelial thickness, and cell-type ratios) with the morphology of mature sperm across our species.

S2.11 HALSEY, LG; University of Roehampton;
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'Fit for purpose' and 'in the best of shape': exploring how physical fitness and body morphology might impact movement ecology

First, I will raise and discuss the proposition that, similarly to Westernised human populations, some animals can only 'keep fit' by undertaking voluntary exercise, and that keeping fit may be vital for key behaviours such as escaping predators and out-competing conspecifics. In turn, the time and energy costs of such voluntary exercise could have important ecological implications. Yet at least some animals appear to be able to 'get fit' without increasing activity levels; are such adaptations associated with life history and/or ecology? … But presumably staying in shape is only worthwhile for an animal if it has a good shape to start with; second, I present empirical evidence arising from my recent work on how inter-individual variability in morphology can affect movement economy in challenging habitats. Specifically, parkour athletes repeatedly traversed a course designed to elicit movement behaviours emulating those of arboreal primates, and we observed that in general their energy economies of locomotion improved as they became familiarised with that course. However, those athletes with relatively long arms and relatively short legs were the better able to find energy savings over repeated attempts at the course. I finish by considering why such a morphology might be advantageous in this particular scenario and how this relates to our understanding of arboreal ape evolution.

P1.253 HAMLET, CL*; TYTELL, ED; FAUCI, LJ; HOFFMAN, KA; Bucknell University, Tufts University, Tulane University, Univ. of Maryland, Baltimore County; *ch051@bucknell.edu*

A Computational Model of a Swimming Lamprey Driven by a Central Pattern Generator with Proprioceptive Feedback

The swimming of a relatively simple vertebrate, the lamprey, can shed light on how a flexible body can couple with a fluid environment to swim rapidly and efficiently. Animals use proprioceptive sensory information to sense how their bodies are bending, and then adjust the neural signals to their muscles to improve performance. We will present recent progress in the development of a integrative, computational model of a swimming lamprey coupled to a Navier-Stokes fluid using an immersed boundary framework. A simple central pattern generator model, based on phase oscillators, is coupled to the evolving body dynamics of the swimmer through curvature feedback. We will examine how the emergent swimming behavior and cost of transport depends upon these functional forms of proprioceptive feedback chosen in the model.

P2.221 HAMMOND, T.T.*; PIGAGE, H.K.; Univ. of California, Berkeley, Univ. of Colorado, Colorado Springs; *talisintess@gmail.com*

Environmental and Endogenous Factors Predicting Flea Assemblages in Two California Chipmunks

Documenting potential vector species is an important first step in understanding the dynamics of vector-borne diseases. Plague, caused by Yersinia pestis, is a bacterial disease transmitted by multiple flea species, which are hosted by a variety of small mammals. In the Sierra Nevada mountains, sciurids and their fleas are important in the maintenance and transmission of plague. While many of these species are regularly tested for plague, in some cases relatively little is known about the specific ectoparasite assemblages they host. In particular, flea communities of the lodgepole chipmunk (Tamias speciosus) and especially the alpine chipmunk (T. alpinus) have been characterized infrequently, and usually with low sample sizes. These species are not primary transmitters of plague - though T. speciosus is known to transmit and succumb to the disease - however, they are of broad interest because they have exhibited divergent elevational range shifts over the past century, possibly due to climate change. Therefore, characterizing ectoparasitism in these species may shed light on the dynamics of flea infestation and disease transmission in changing environments. Here we report results from a study of T. alpinus (N=298) and T. speciosus (N=1014) trapped and combed for fleas in 2013-2015. The primary goals are to characterize the relationships between flea species and abundance and (1) host species; (2) host endogenous factors (species, sex, mass, behavior); (3) environmental factors (temperature, habitat). Ultimately, this study will help to establish ecological baselines for the focal species and will clarify the relationships between host, fleas, and environment in a plague- and climate-change-relevant system.

98.5 HAN, Y*; LUO, Y; BI, J; LI, C; Johns Hopkins University; *yhan33@jhu.edu*

Body shape affects yaw and pitch motions of insects traversing complex 3-D terrains

Analogous to fusiform shapes that reduce fluid-dynamic drag, terradynamically streamlined shape was recently discovered: cockroach's ellipsoidal body shape facilitates body roll to slip through gaps between cluttered obstacles. Here, we hypothesize that there exists a broader range of terradynamic shapes that facilitate other modes of locomotion like turning and climbing in complex 3-D terrains. To test our hypothesis, we modified the body shape of the discoid cockroach (*Blaberus discoidalis*) by adding an oval and a rectangular shell to its back, and studied how it traversed vertical pillars. To efficiently obtain statistically meaningful data, we developed an automated system to motivate the animal to run through terrain modules and capture videos for 3-D kinematics analysis. Cockroaches with an oval shell traversed round and square pillars within 0.4 ± 0.2 s and 0.4 ± 0.2 s, significantly more quickly than those with a rectangular shell within 1.6 ± 0.7 s and 2.9 ± 0.7 s ($P < 0.001$, ANOVA). We discovered that an oval body shape facilitated body yawing while a rectangular body shape facilitated body pitching. Upon colliding with and pushing against the obstacle, animals with an oval shell always turned *away* from it (100% probability for both round and square pillars). By contrast, animals with a rectangular shell more often turned *towards* the obstacle (70 ± 17 % for round and 91 ± 7 % for square pillars). In addition, animals with a rectangular shell pitched up more often and (27 ± 14 % for round and 43 ± 16 % for square pillars) than those with an oval shell (18 ± 17% and 24 ± 19 %) ($P < 0.001$). We developed a locomotion energy landscape model to begin to explain our observations. Our study provides inspirations for robots to use morphing shapes to traverse obstacles in challenging terrains like building rubble.

53.5 HANEY, WA*; SUEDA, S; CLARK, AJ; UYENO, TA; Valdosta State University, Texas A&M University, College of Charleston, Valdosta State University ; *wahaney@valdosta.edu*

3D Analysis of Knotting in Hagfish

Hagfish possess a relatively rare flexibility that allows them to tie their bodies into knots. These knots can be worked along the length of their bodies to clean off mucous, escape tight spaces, pull prey from burrows, and possibly replace the leverage commonly generated by an opposing jaw. Knotting supports these crucial functions because the loops may be pressed against a surface to create leverage. A first step in understanding the knotting behavior is to characterize knot formation. In this study, we describe the kinematics of how hagfish form, and then manipulate, the body knot. Preliminary results showed that knotting may be stereotyped, however the low-resolution frame-by-frame kinematic analysis only weakly supported this assertion. To more robustly describe how hagfish tie body knots, we have developed an enhanced kinematic analysis. We employed a custom restraint device to consistently and controllably induce knotting in 20 individuals of *Eptatretus stoutii* (Pacific hagfish) and 4 individuals of *E. springerii* (Gulf hagfish). We used two high-speed cameras (200Hz) to capture the right-lateral and ventral views. Using custom software, we automatically isolated the body of the hagfish in each frame of the video for both camera views. Careful calibration of the camera and tank geometry allowed us to create a point cloud. This was used to create a surface mesh of the body that depended on semi-automatic user guidance to make sense of noise in the point cloud. The resultant mesh animation allowed us to quickly generate a high-resolution kinematic analysis that included body deformations resulting from formation and manipulation of knots. We are currently working on fully automated methods of surface mesh creation.

P2.220 HANNAH, SM*; MUNOZ, JM; MULCAHY, C; FONTAINE, C; FIELD, C; WHORISKEY, S; JOHNSON, S; LAUER, A; MCDONALD, G; LIWANAG, H; MLML, CSUB, TMMC, TMMC, Cal Poly SLO; *shwnhannah14@gmail.com*
Coccidioidomycosis in stranded marine mammals along California's coast
Marine mammals along the California coast can be infected with Coccidioides, a fungal pathogen endemic to land. Disseminated infection with this pathogen is known as coccidioidomycosis, or valley fever. Infective fungal spores (arthroconidia) are from two species: *Coccidioides immitis*, endemic to California, and *Coccidioides posadasii*, present from South America through the southwestern US. These spores become airborne from disturbed soil. Increased soil disturbance during the ongoing drought in California has increased valley fever episodes in humans, but little is known of the frequency of exposure in marine mammals. Results from blood serum assays (IgG and IgM) have shown that 16% of California sea lions and northern fur seals with respiratory symptoms at California marine mammal rehabilitation facilities have antibodies against coccidioides. With these results in mind, we evaluated a coccidioidomycosis diagnostic tool never before used on marine mammals: the SPHERUSOL skin test. SPHERUSOL is an intradermal mitogen test used to detect antibodies to Coccidioides in humans. We compared immunodiffusion assays on blood serum of sea lion and fur seal patients at The Marine Mammal Center (TMMC) with the results of SPHERUSOL skin tests to validate the skin test for use on pinnipeds. This test could potentially diagnose coccidioidomycosis in pinnipeds before dissemination, and may allow faster treatment with anti-fungal agents for a better prognosis. Overall, this project will improve our knowledge of where arthroconidia travel under the current conditions in California and how this may affect both marine mammals and humans in coastal areas.

125.4 HARADA, AE*; BURTON, RS; Scripps Institution of Oceanography, Univ. of California, San Diego; *aharada@ucsd.edu*
The Mitochondrial Basis of Thermal Tolerance in the Intertidal Copepod Tigriopus californicus
Populations of conspecifics that are distributed across a wide latitudinal range allow for the study of adaptation to varying local environments. *Tigriopus californicus* is a copepod found in high rocky tide pools along the west coast of North America. The relative genetic isolation of different populations, coupled with the range of thermal regimes to which they are exposed, make it an ideal study system for examining the evolution of thermal tolerance. Previous studies have shown that the southernmost populations of *T. californicus* have the highest survivorship following acute heat stress. In this study, we examine the physiological basis of heat tolerance. We hypothesize that adaptation among populations leads to differences in mitochondrial thermal performance and confers enhanced tolerance to southern populations. In order to understand the physiological basis for thermal tolerance, we measured ATP production, ROS presence, membrane potential, and electron transport system activity in both northern and southern populations. Despite common garden acclimation, we found differences in mitochondrial performance between northern and southern populations. Furthermore, we found evidence that suggests mitochondria are more thermally sensitive than whole animals. These results may indicate that mitochondria have an important role in setting the range limits of *T. californicus* populations and that nuclear and mitochondrial genes involved in mitochondrial functions may be targets for selection leading to adaptation to the thermal environment.

45.7 HARBISON, CW*; BOUGHTON, RM; SHINE, PJ; MAGIERA, AL; Siena College; *charbison@siena.edu*
Thermo-orientation Influences Ectoparasite Navigation and Microhabitat Selection on Hosts
Many ectoparasites move to and exploit specific body regions after hosts are acquired. Often, migration routes to these preferred regions are predictable, which suggests parasite movement is directed. We used a model system consisting of feather-feeding lice (*Columbicola columbae*) and their bird hosts (*Columba livia*) to understand how thermal cues influence microhabitat selection and to reveal the control mechanisms governing thermo-orientation. We first determined whether lice responded to thermal cues, then tested whether thermo-orientation helped guide their repeated migrations between flight feathers (where they hide from bird preening) and bird body regions (where they feed). We found that lice can accurately direct their movements towards heat targets, can distinguish between temperatures found on bird body regions and those found on the flight feathers, and will alter their temperature preferences when starved towards those found on bird body regions where they feed. Taken together, these results indicate that host-generated thermal cues play an important role in louse movement and microhabitat selection on their hosts. Finally, we exposed lice with two and one antennae to temporal and spatial heat gradients and analyzed their paths using motion-tracking software to better understand the control mechanisms governing thermo-orientation. We found that lice were capable of orienting to heat targets using only idiothetic (internally stored information) control mechanisms. However, they likely rely on a combination of idiothetic and allothetic (external information) control mechanisms during thermo-orientation.

P1.48 HARBISON, CW*; AHMED, ZB; SULLIVAN, TJ; Siena College; *charbison@siena.edu*
Pheromone-mediated Communication in a Bird Ectoparasite
Pheromone-mediated communication governs many aspects of insect behavior, population dynamics, and community ecology. For insect parasites, understanding the language of chemical communication may offer new insights into host-parasite interactions and provide novel strategies for combating parasites. Here, we study the possibility of pheromone-mediated communication in a feather-feeding louse (*Columbicola columbae*). These small parasites (~2 mm long) spend the large majority of their time hiding between the coarse barbs of flight feathers, and must periodically migrate to bird body regions to feed on insulative downy feathers. Using a Y-tube olfactometer, we show that lice readily move up the arm containing either male or female lice as compared to the arm without lice, demonstrating their ability to produce and orient to volatile pheromones. Interestingly, when forced to choose between an arm containing males and an arm with females, males strongly preferred the male arm while females preferred the female arm. This suggests the use of sex-specific pheromones. Finally, we show that pheromone production in lice appears to be dependent on their location on the host. Lice overwhelmingly moved up the arm towards those placed on flight feathers, whereas there was no preference for either arm when lice were placed on bird body feathers or kept in an arm without feathers. This suggests that lice produce pheromones only when located on their preferred host region (flight feathers), and can help explain their clumped distribution on flight feathers. We are currently working to determine the structures of volatile compounds produced by lice and to identify their use in pheromonal communication.

124.1 HARDY, AR*; HALE, ME; Univ. of Chicago; *arhardy7@uchicago.edu*

Touch sensation by fins of bottom dwelling fish and the encoding of substrate surface features

The fins of bottom dwelling fishes often touch substrate and may deform in response to that contact. Here we investigate the capability of the fin mechanosensory system to resolve fine details of associated substrate. While the tetrapod somatosensory system exhibits fine tactile sensitivity capable of resolving sub-millimeter textural features via mechanoreceptors with small diameter receptive fields, it is unknown whether fish fins can encode such detail on the shape and roughness of the substrate. Sensory feedback on surface features could modulate a variety of substrate-based behaviors such as orientation or station holding. In this study we examined the pectoral fins of the bottom dwelling Round Goby (*Neogobius melanostomus*), an invasive species common to sandy and rocky bottoms of Lake Michigan. Using a linear brush stimulation we identified afferents that exhibited receptive field sizes similar to those found in the mammalian system, suggesting that they have the capability to discriminate aspects of fine tactile stimuli. To examine this possibility, fin ray nerve fiber activity was recorded in response to a rotating 3D printed drum with grating and embossed dot patterns. We found that afferents encode millimeter-sized features across a range of speeds (10 - 100 mm/sec), indicating similar levels of resolution to tetrapod tactile sensation. Immunostaining revealed putative mechanoreceptors located primarily in the fin membrane directly adjacent to each ray and differences between leading and trailing edge fin rays were found. This study suggests that fins of bottom dwelling species may be well suited to encode detailed surface features of their habitat and that limb based texture perception is not a unique feature of sarcopterygians.

P2.252 HARMON, JL*; PARKER, G; OLSEN, M; GSTREIN, G; VANDENBROOKS, JM; Midwestern University; *jharmon82@midwestern.edu*

Tracheolar and mitochondrial investment varies with developmental pO_2 in Drosophila melanogaster

Atmospheric oxygen has wide ranging effects on insect physiology including changes in body size, development, lifespan, and fecundity. Recently, several studies have shown an effect of oxygen on the tracheal system of insects. A limitation of these studies has been a focus on the supply side and only imaging the large conducting tracheae or a small area of the tracheoles Here we have used confocal imaging to image both the oxygen supply side (the tracheal system) and the oxygen demand side (the mitochondria) of the flight muscle in *Drosophila melanogaster* that have been reared in oxygen levels ranging from 12kPa to 31kPa. Using genetically modified *D. melanogaster* that have a yellow-fluorescing protein (YFP) inserted into their mitochondrial membrane, we have been able to create 3D renderings of both the mitochondrial and tracheolar networks, which auto-fluoresce in the green spectrum. This allows us to simultaneously analyze the effect of developmental oxygen on the relative volume investment and network patterns of both components. Using this technique and analyzing the images in Image Pro Premier, we have been able to co-localize the mitochondrial network with the tracheolar network and show that mitochondrial to tracheolar distances vary with rearing oxygen. Interestingly, it appears both tracheolar investment and mitochondrial investment are inversely correlated with rearing oxygen. This suggests that insects invest more in their respiratory network to ensure adequate oxygen delivery. At the same time, they invest more in their mitochondrial system to ensure metabolic efficiency during periods of high performance. The results of these studies demonstrate that atmospheric oxygen availability strongly affects both the supply and demand side of insect respiratory systems.

10.5 HARNESS, N*; SCHUL, J; University of Missouri; *Harness@gmail.com*

The origin of complex calls: inferences from phylogeny and function

Among closely related groups meadow katydids have unusually complex calls, consisting of buzzing and ticking phrases. In some species the tick/buzz pattern is highly stereotyped, while in others it is variable both within and between males. This makes them an excellent system for a comparative study of complex call evolution. In all species tested buzzes are necessary and sufficient to attract females. In some, but not all, species the ticking phrase increases attractiveness. Here we test the importance of ticks for male-male interactions. First we compared solo and group calling: in all species tested, males produced more tick phrases while group calling. Within each group the male starting a calling bout produced a higher proportion of ticking phrases. In arena experiments males chose their calling position in the presence of a call playback. Stimulated with natural patterns, males showed significant spacing. With buzzes alone, males moved much closer to the speaker. With ticks alone, the distance increased significantly. Our findings support the hypothesis that tick phrases evolved in the context of male-male interactions and were later incorporated into male-female communication.

P2.52 HARPER, GR; Hendrix College; *harper@hendrix.edu*

Evolution of the Phospholipase A2 Venom Gene in the Five Subspecies of Copperheads (Agkistrodon contortrix)

Copperhead snakes (*Agkistrodon contortrix*) are widely distributed in the United States and have been divided into five subspecies. Observation of regional behavioral differences in striking behavior within Arkansas copperheads led us to look for differences in the venom of the subspecies of copperheads. Because venom is a key adaptation in viper food acquisition, differences in the abundance, form, and activity of various venom components are likely to lead to differences in prey capture behavior. Phospholipase A2 (PLA2), a myotoxic component of copperhead venom, is an important protein in many snake venoms either as an enzymatic component or as a toxin. The aim of this study was to isolate and sequence the genomic PLA2 genes from all five subspecies to understand whether these genes have diversified within the species, and if so what effect the variations might have on the protein. We isolated and sequenced PLA2 genes from individuals of all five subspecies, and found distinct differences in the nucleotide sequences and the predicted amino acid sequences between the subspecies. Some of the differences correlate with known differences in PLA2 potency. A phylogenetic analysis of the PLA2 sequences allowed us to examine a snake of unknown subspecific designation from an area of integration in the Ozarks of Arkansas. This snake showed sequences that closely associated with sequences from two different subspecies. In addition, the sequences we obtained allow us to test whether these genes are evolving through drift, selection, or a combination of the two.

132.5 HARRIGAN, KM*; MOORE, PA; Bowling Green State University; *kharrig@bgsu.edu*

Scaling to the Organism: An Innovative Model of Dynamic Toxic Hotspots in a Stream System

Anthropogenic pollutants have devastating consequences on the nation's freshwater supply and effect not only the quality of the water, but the health and viability of the organisms that live within the ecosystem. While the movement and impact of toxins at large scales have been extensively studied, the examination of exposure to a pollutant at the scale of a single organism has been non-existent. Aquatic organisms may be experiencing different concentrations of anthropogenic pollutants depending on their location within the water body. The purpose of this experiment was to identify "hot" and "cold" spots of toxic exposure in different locations of a stream based on fluid dynamics. These data will be used to infer what organisms might be exposed to under different flow conditions. Data was collected in a series of artificial streams (approximately 17.4 x 0.98 x 0.39 m) using dopamine as a chemical tracer. The dopamine was measured in a riffle, pool, bend, woody debris, sand, and gravel sections of the stream using an electrode and electrochemical detection system. The data was imported into ArcGIS 10.3.1 (Esri, Redlands, CA) to create maps demonstrating the chemical distribution throughout the varying stream features. Preliminary data analyses provide indication of potentially more toxic areas of a stream for organisms compared to others based on the interaction of hydrodynamics, stream hydrology, and physics. Our findings are beneficial to not only our understanding of chemical movement, but in determining which areas of a stream need to be focused on for conservation and mitigation efforts.

80.5 HARRIS, RL*; DREA, CM; Duke University, Durham NC; *rlh44@duke.edu*

In Sickness and In Health: Olfactory Cues of Injury and Illness in Lemurs

Understanding the biological and physiological parameters associated with changes in animal health is critical for improving our insights into evolutionary processes associated with condition-dependent signaling. In mammals, complex olfactory ‘signatures' communicate stable characteristics (species, sex, identity) to conspecifics, but can also be condition dependent, varying with health status, parasite load, and disease. The latter suggests that, like other signals, scent signals may be energetically expensive to maintain, with resources being diverted to recovery processes. Fundamental gaps in our understanding of the relationships between scent signals and host health, particularly in non-model, non-laboratory species, means that an olfactory version of the ‘expensive or honest signal hypothesis' remains to be further tested. We investigated the effects of health (wellness, injury, illness) on chemical signals in the ring-tailed lemur (*Lemur catta*), a socially integrated, but highly aggressive, strepsirrhine primate. This species boasts a complex, sexually differentiated repertoire of scent-marking behavior, involving both stable and transient olfactory cues. We paired genital odorant composition (from gas chromatography-mass spectrometry analyses) with health status (from veterinary records) in 24 adult, captive *L. catta* across periods of wellness, injury/illness, and recovery. Scent signals became drastically ‘muted' during the period of insult, showing significant decreases in chemical richness and diversity, and altered composition. Based on these results, we suggest that, when unwell, animals are unable to bear the costs of producing their normal olfactory signature. These changes are likely to be salient to conspecifics and could alter social behavior, group dynamics, and potentially mate choice. Funded by NSF IOS-0719003.

135.1 HARRISON, J.F.; Arizona State University; *j.harrison@asu.edu*

Hypometric scaling of metabolic rate arises from size-dependent natural selection on ATP demand

In animals, and animal colonies, but not plants, protists or bacteria, larger organisms have lower metabolic rates per gram. Prominent hypotheses suggest that this pattern arises from physiological constraints on energy production in larger animals, either due to declining surface/volume ratios or increasing resistance to flow. However, safety margins for oxygen delivery do not decline in larger animals, and larger vertebrates do not disproportionately invest in oxygen supply structures as occurs in other contexts when oxygen is limiting. Hypometric scaling of animal metabolic rate derives from body-size dependent selection on ATP demand. Large animals prey on smaller ones, and small and large animals compete for similar resources, causing greater selection on smaller animals to achieve high neurolocomotory performance. Greater selection for neurolocomotory performance selects for relatively larger brains, higher accelerations, and higher mass-specific metabolic rates. Also, small animals can utilize physically and temporally smaller ecological niches, selecting for faster growth and development rates, also requiring higher mass-specific metabolic rate. Conversely, larger animals with delayed reproduction and longer lifespans experience greater selection to reduce metabolic rates to reduce vulnerability to predation, starvation and infection. Size-dependent selection on metabolic rate is mediated by genes that exhibit antagonistic pleiotropy, with positive effects on growth and reproduction traded off vs. negative effects on longevity and stress-resistance. Supported by NSF IOS 1256745 and 1122157.

129.8 HARRISON, J.S.*; HIGGINS, B.A.; MEHTA, R.S.; Duke University, Univ. of California, Santa Cruz; *jacob.harrison@duke.edu*

Scaling of Dentition and Prey Size in the California Moray (Gymnothorax mordax)

Scaling patterns of tooth morphology can provide insights on prey capture strategy and dietary patterns as species grow through ontogeny. We report the scaling of dentition and diet and how it relates to body size in the California moray, *Gymnothorax mordax*. We sampled lengths, widths, and curvature for teeth lining five distinct regions of the oral jaws across twenty-one *G. mordax* individuals ranging from 383-1110 mm total length (TL). Absolute tooth length in relation to moray size shows positive allometry only for the outer maxillary teeth, while teeth lining the inner maxilla display positive allometry in tooth base width. All other regions exhibit isometric growth in both length and width relative to moray size. Similar to previous descriptions of other moray species, the longest teeth in the oral jaws are the median intermaxillary teeth. This series of three teeth are depressible and rooted in the center of the ethmovomer, the bone that forms the roof of the rostrum. We hypothesize that caudal mobility of the median intermaxillary teeth aid in prey transport by enabling the pharyngeal jaws to remove pierced prey without requiring full abduction of the oral jaws. The predominantly isometric tooth growth in *G. mordax* suggests that the oral teeth grow proportionately as individuals increase in size. Stomach contents from the field suggest that *G. mordax* is highly piscivorous. While a strong positively allometric relationship between vertical gape and head length supports the expectation that moray increase relative prey size over ontogeny, we found no relationship between prey standard length and moray size. This suggests that while larger individuals are capable of consuming larger prey, individual *G. mordax* are opportunistic predators that do not specialize on prey of a specific size over ontogeny.

P2.49 HARWOOD, AL*; HICKEY, MG; PODOLSKY, RD; College of Charleston; *harwoodal@g.cofc.edu*

An Experimental Test of Sexual Selection for Large Male Size in Pycnogonids

Sexual size dimorphism is a common feature of animals with complex mating behaviors. Sexual selection offers one possible explanation for larger male size: larger males may have an advantage in mating, either because females prefer larger males or because larger males have a competitive advantage in access to females. In pycnogonids, successful mating by males can be deduced from their possession of egg sacs, which they collect from females, fertilize, and then carry during embryonic development. We used this aspect of reproduction to assess the mating success of males with different characteristics. Our previous work on the pycnogonid *Tanystylum orbiculare* found that mated males collected from the field were larger than unmated males, and that the number of egg masses carried correlated with male body size, suggesting that male size might provide a mating advantage. To test this hypothesis experimentally, we collected unmated individuals from the field and arranged them in triads that included two males and one female. Males in each triad were selected from the size distribution so that there was a clear and similar size difference between them (e.g., the largest male paired with the male just below the median size, and so on going down in size). In most cases where egg sacs were produced, the female mated with the larger male first. In some cases the smaller male was mated second, indicating that smaller males were reproductively competent. Our results support the hypothesis that larger males have a mating advantage that may help to drive selection for large male size. Future work will address whether this advantage results from female choice or male-male competition.

121.5 HASKINS, D.L.*; HAMILTON, M.T.; STACY, N.I.; TUBERVILLE, T.D.; University of Georgia's Savannah River Ecology Lab, University of Florida; *david.haskins@uga.edu*

Effects of selenium on the hematology, innate immunity, and metabolic rate of yellow-bellied sliders (Trachemys scripta scripta)

Selenium (Se) is a naturally occurring, essential element that can be toxic to vertebrates in high concentrations. Despite studies that have shown that reptiles can accumulate copious amounts of Se in the wild, little is known on toxicologic effects of Se. In this study, we exposed 70 juvenile yellow-bellied sliders (Trachemys scripta scripta) to seleno-L-methionine via oral gavage for a total of five weeks. Turtles were placed into one of three treatment groups (control, n = 24; 15mg/kg, n = 23; and 30 mg/kg, n = 23). At the conclusion of the experiment, turtles were sacrificed and kidney, liver, muscle, and blood samples were collected for Se analysis. Turtles in the Se treatment groups accumulated significantly higher amounts of Se in all tissue types relative to controls. Although toxicity thresholds for reptiles do not exist, selenium concentrations in both Se treatment groups exceeded avian toxicity thresholds in liver tissues. We found that oxygen consumption and innate bactericidal capacity were not impacted by Se exposure. However, turtles in the 30 mg/kg group exhibited anemia and evidence of immunosuppression (i.e., decreased absolute lymphocytes), which have been described in other vertebrates in response to Se exposure. Furthermore, exposure to the 30 mg/kg Se treatment resulted in 17% (4/23) mortality of juvenile T. scripta. To our knowledge, this study is the first to report Se-induced immunosuppression or mortality in a reptilian species.

P3.53 HATFIELD, L*; WINTERS, GC; BOSTWICK, CJ; PAULAY, K; KOHN, AB; MOROZ, LL; Bridgewater College, Whitney Lab Univ. Florida; *lh002@eagles.bridgewater.edu*

Deciphering the Molecular Identity of Cells in Known Memory Circuits

The central nervous systems of *Octopus* and *Aplysia* molluscs differ extensively. Octopods have centralized brains as well as highly flexible behavior. On the other hand, *Aplysia* nervous systems are made up of ganglia throughout the body cavity. Despite these organizational differences, *Aplysia* and *Octopus* share common aspects of memory integration circuitry. In both circuits information (visual or tactile input from an external stimulus) travels from sensory neurons, is modulated by interneurons, and finally output via motor neurons. Many memory circuits share conserved features and are often regulated by signaling molecules like neuropeptides. Although cellular architecture of the *Octopus* Vertical Lobe (VL) and the *Aplysia* abdominal ganglion memory circuit have been described, the breadth of molecules used for cellular communication within the circuit is unknown. To address this, we dissociated and analyzed the cells of *Octopus* VL and *Aplysia* memory circuits. We used state-of-the-art single-cell RNA-seq and traditional molecular biology tools to identify and localize novel and conserved signaling molecules in molluscan memory systems. Comparative analysis led to the conclusion that some peptides may be conserved in functionally-similar neurons, while others may have functionally diverged, based on the levels of expression in different cell types. *Octopus* memory circuitry was found to be unique and innovative. Transcriptome analyses of individual neurons led to the identification of Login, a novel peptide, as well as potential subgroups of large efferent neurons within the *Octopus*. Even though diverse molluscs share similar memory architecture, the molecules modulating function may be different in *Octopus* and *Aplysia*.

96.2 HAU KWAN, L*; KIT YU, KC; Hong Kong University of Science and Techonology; *hkloab@connect.ust.hk*

Legacy effect of microplastic ingestion on growth and development of the slipper limpet Crepidula onyx

Plastic pieces that are less than 5 mm diameter, microplastics, are considered as an increasing threat to marine organisms due to their high abundance, persistence nature, and absorption of other pollutants. However, little is known about effect of ingesting microplastics during early stage on later developmental stages despite many marine invertebrates have complex life histories. Here, we used a two-stage experiment to first expose the *Crepidula onyx* veliger larvae to algal diet with the addition of micro-polystyrene (micro-PS) and we subsequently presented them with a normal algal diet without micro-PS after settlement. Although the larvae selectively fed on algae and against the micro-PS, they grew at a slower rate which suggests that ingestion and/or removal of micro-PS cost energy. These micro-PS fed larvae also settled at a smaller size compared to the control groups which are fed only with algae, such decrease in size could reduce post-settlement success in the field. In the second experimental stage, juvenile *C. onyx* survived but had slower growth rates when micro-PS were continuously added to their diets. Surprisingly, the growth rate of juveniles remained slower than those in control even if micro-PS was not given to them for 65 days after the initial larval exposure. This observed legacy effect highlights the importance of considering long-term impacts and risks of microplastic pieces, even after removing them from the environment.

P1.16 HAVENS, LT; Univ. of South Carolina, Columbia; *lukethavens@gmail.com*

Using autonomous robots to teach neuroethology

Bridging the conceptual gap between neural circuitry and behavior remains a significant challenge in neurobiology education. The perceived complexity of behavior keeps many students from attempting to break actions into constituent parts, and without the context of these behavioral building blocks understanding their controlling circuitry becomes infeasible. To address this challenge, I designed a series of laboratory exercises using autonomous robots built with the Arduino platform and drawing from Braitenberg's *Vehicles* as a major source of inspiration. These experiments allowed students to interact with and manipulate the neural circuits and behaviors they studied in order to demonstrate the relationship between the two and the emergent nature of behavior. The first exercise challenged students to explain the stereotyped behavior of freely-moving robots using simple rules in the form of "if-then" statements connecting environmental stimuli to behavior rather than assigning the organism motivation. After this, I led students to translate these rules into neural circuitry and showed how these simple rules or circuits could be translated into computer code. Finally, students designed and programmed their own robots with biologically-inspired behaviors such as environmental navigation, communication, and predator-prey interaction. Through this process, students were challenged to think more analytically about animal behavior and its connection to neural circuitry as well as the emergent nature of behavior and the limitations imposed on it by sensors and actuators. The basic level of electronics design and programming competency these exercises gave students and the effectiveness of the robots as an educational tool made them a welcome addition to our neurobiology laboratory curriculum.

11.3 HAVIRD, J.C.*; SLOAN, D.B.; Colorado State Univ.; *justin.havird@colostate.edu*

Do mitochondria create species boundaries or ignore them? Evidence from a plant lineage with fast-evolving mtDNA

Mitochondria are a key feature of eukaryotes, and the presence of a mitochondrial (mt) genome in most eukaryotic lineages creates a dynamic of coevolution and conflict with the larger nuclear genome. Several lines of evidence suggest that the nuclear genome must undergo compensatory changes to offset the effects of changes in the mtDNA, which may be under less efficient selection. This creates specific mitonuclear combinations that are "matched" within a population or species, but hybridization between species can lead to mitonuclear "mismatch" and decreased fitness in hybrids. Therefore, mtDNA and mitonuclear interactions have been implicated as primary drivers of speciation in eukaryotes. On the other hand, mtDNA fluidly crosses species boundaries in many hybrid zones, and so-called "mitonuclear discordance" is rampant among animals. To reconcile these seemingly opposite findings, we suggest that they are two evolutionary solutions to the same problem: accumulation of deleterious mutations in mtDNA. Compensatory changes in the nuclear DNA can offset mt-induced harm, leading to mitonuclear match and creating species boundaries. Alternatively, mutation-ridden mtDNA can be replaced by a more fit mt genome from a closely related species. Here, we will present cases of these two scenarios from the available literature, make predictions as to when each would be expected, and suggest future studies to test these hypotheses. We also present relevant results from a case study of *Silene*, an angiosperm genus with variable rates of mtDNA evolution among closely related species and a history of mitonuclear coevolution.

S2.6 HAWKES, LA*; BATBAYAR, N; BUTLER, PJ; CHUA, B; FRAPPELL, PB; MILSOM, WK; NATSAGDORJ, T; NEWMAN, SH; SCOTT, GR; SPIVEY, RS; TAKEKAWA, JY; WIKELSKI, WITT, BISHOP, M, MJ, CM; University of Exeter, Penryn Campus, Penryn, Cornwall, TR10 9FE, UK, Wildlife Science and Conservation Centre, Ulan Bataar, Mongolia, University of Birmingham, School of Biosciences, Birmingham B15 2TT, UK, University of British Columbia, Department of Zoology, 6270 University Blvd, Vancouver, V6T 1Z4, Canada, University of Tasmania, Sandy Bay Campus, Private Bag 3, Tasmania 7001, Australia, Food and Agriculture Organisation of the United Nations, Viale delle Terme di Caracalla, Rome 00153, Italy, McMaster University, Department of Biology, 1280 Main Street West, Hamilton, Ontario L8S 4K1, Canada, Bangor University, School of Biological Sciences, Bangor, Gwynedd LL57 2UW, UK, National Audubon Society, 220 Montgomery Street, Suite 1000, San Francisco CA 94104-3402, USA, Max Planck Institute for Ornithology, Schlossallee 2, 78315 Radolfzell, Germany; Bangor University, School of Biological Sciences, Bangor, Gwynedd LL57 2UW, UK; University of Exeter, Environment and Sustainability Institute, Penryn Campus, Penryn, Cornwal; *l.hawkes@exeter.ac.uk*

Do bar-headed geese train for high altitude flights?

Exercise at high altitude is extremely challenging, largely due to hypobaric hypoxia (low oxygen levels brought about by low air pressure). Studies of humans at extreme high altitude on Mount Everest have demonstrated precipitous declines in blood oxygen content above 8,400 metres and consequently very few humans have summited Mount Everest without supplemental oxygen and only do so after considerable acclimatisation and /or training. The bar-headed goose (*Anser indicus* is a renown high altitude migrant and although it appears to minimise altitude during migration where possible, makes steep climbs from India over the Himalayan mountain range. This requires considerable cardiovascular effort, without acclimatisation, but no work has assessed the extent to which geese may train prior to the migration. Using implanted heart rate loggers and accelerometry, we investigate the extent to which ‘training' may take place and discuss the strategies used by bar-headed geese in the context of training for altitude in human mountaineers, noting the differences between their respective cardiovascular physiology.

45.6 HAYDEN, MJ*; ONTHANK, K; Walla Walla University; *haydenmaureen11@gmail.com*

Thermal Preference in the Smoothskin octopus (Muusoctopus leioderma)

In 2014 a population of smoothskin octopuses (*Muusoctopus leioderma*) was discovered in Burrows Bay, WA at a depth of 13m, the shallowest recorded depth for this deep water species. The occurrence of these octopuses in shallow water raises the question what is the prefered temperature for this octopus species.The average temperature at the east entrance of the Strait of Juan de Fuca near Bowman's Bay at depth near the upper limit of the known range of *M. leioderma* of 113m is 7 °C and the temperature of Burrows Bay where octopuses have been collected is 13°C. This creates two possible temperature preferences for *M. leioderma*, deep water (7°C) or shallow water (13°C). The purpose of the study was to determine the temperature preference of *M. leioderma*, as a lower temperature preference would support the hypothesis that this population is a recent immigrant to shallow water. Temperature preference of 17 *Muusoctopus leioderma* was determined using a thermal gradient, during three hour trials. Also, total movement was measured over a range of temperatures (4,7,9,11,13°C) in a shallow, temperature controlled aquarium. Movement of octopuses during the thermal gradient and activity trials was recorded with cameras taking time-lapse images every 20 seconds. Oxygen consumption was measured using open respirometry at a range of temperatures (4, 7, 10, 13°C) over 10 hours. This data did not show that *Muusoctopus leioderma* has a strong preference between 7 and 13°C. The lack of evidence for a temperature preference does not support either hypothesis for this population of *M. leioderma* being a recent immigrant to shallow water in the Salish Sea or if there is a long term population.

P1.189 HAYES, MM*; ARMBRUSTER, JW; SUMMERS, AP; Auburn University, Friday Harbor Laboratories University of Washington; *malorie.hayes@auburn.edu*

Comparative Morphology of the African Small Barbs, Enteromius

Barbs are a large group of freshwater cyprinid fishes with over 800 nominal species species in 33 genera spread across Asia, Europe, and Africa. Their morphological and genetic diversity rivals the more well-known cichlid fishes, and they have radiated over a much larger geographic area. Asian barbs are currently the most speciose group; however, this may be due to the paucity of taxonomic work in African taxa. The African small barbs (ASB), *Enteromius* and related genera, is a group in need of particular study with regards to its morphological variation. Preliminary molecular work recognizes the non-monophyly of *Enteromius* and suggests additional genera will need to be described or elevated. We used CT scanning examine morphological characteristics of member clades, scanning 138 species at a resolution of 6μm - 71.4μm. We examine the structure of the cranium, pharyngeal jaws, and Weberian apparatus and use 3D geometric morphometrics to describe traits useful for distinguishing clades of ASB. Exemplar taxa for the clades are presented that provide a clearer picture of the pattern of morphological evolution within this group.

103.7 HAYFORD, HA*; CARRINGTON, E; University of Washington; *hayford@uw.edu*

Performance benefits of slow migratory behavior in a predictable dynamic habitat

Behavior plays a fundamental role in regulating the thermal environment experienced by an ectothermic animal. Animal speed and spatiotemporal patterns of environmental variation determine the temporal scale of thermoregulation. Slow animals cannot moderate quickly-fluctuating temperatures by moving between microclimates unless those microclimates are very close together. However, they may use predictable patterns of environmental fluctuation to thermoregulate. Snails are quintessentially slow animals. The marine intertidal snail *Nucella ostrina* is not only a slow walker, but a slow forager. In the intertidal zone, temperature fluctuations are rapid (minutes to hours), but tides limit the potential for thermal extremes to specific days of a two-week cycle. *N. ostrina* makes its prolonged foraging bouts to risky high shore areas only on the days of the tidal cycle that are predictably devoid of thermal extremes. We used observed snail foraging behavior, body temperature from physical thermal models, and thermal performance assays of righting response, to model the environment the snail actually experiences during spring/summer low tide exposure. We found performance of this species drops dramatically after a 2 h exposure above 30°C and mortality is high at 35°C. Our model showed a 60% or greater reduction in low-performance temperatures experienced by a migrating versus stationary snail. This reduction persisted when we considered temperatures 2°C higher as predicted by global climate change. This behavioral filter of environment greatly reduced the proportion of time *N. ostrina* was exposed to thermal risk. This snail is unlikely to be directly affected by thermal costs of climate change because it simply isn't present in times and places where performance-reducing temperatures occur.

P1.131 HEAD, T.B.*; TOMANEK, L.; MYKLES, D.L.; California Polytechnic State University, Colorado State University; *taliabriannehead@gmail.com*

Proteomic analysis of the crustacean molting gland (Y-organ) over the molt cycle

Molting processes are controlled by ecdysteroids produced by a pair of Y-organs (YOs). Cytochrome P450 enzymes convert cholesterol to a polyhydroxylated product (ecdysone), which is hydroxylated to the active hormone, 20-hydroxyecdysone (20E), by peripheral tissues. The YO transitions through four physiological states over the molt cycle; these are designated basal (intermolt), activated (early premolt), committed (mid premolt), and repressed (postmolt). YO activation requires mTOR activity. Two-dimensional gel electrophoresis and matrix-assisted laser desorption ionization tandem time-of-flight (MALDI-TOF/TOF) mass spectrometry were used for proteomic analysis of the YO over the molt cycle. Analysis of the *Carcinus maenas* proteome showed expression of anti-reactive oxygen species (ROS) proteins (e.g., superoxide dismutase, catalase, peroxidoxin 3, cyclophilin A) that neutralize oxygen radicals likely produced from ecdysteroid biosynthesis; a transaldolase that regulates ecdysteroidogenesis; and a glutamate dehydrogenase that links production of α-ketoglutarate to mTOR activation. There were significant changes in protein abundance in the YO in eyestalk-ablated (ESA) and multiple leg autotomy (MLA) molt-induced blackback land crab, *Gecarcinus lateralis*. 457 proteins were detected in the YO of MLA animals, of which 50% changed significantly in abundance over the molt cycle. Comparatively, 358 proteins were detected in the YO of ESA animals, of which 28% changed significantly in abundance. Principle component analysis shows that the basal, activated, committed, and repressed YOs are discrete states. Further analysis will begin to resolve the cellular changes involved in transition of the YO between physiological states. Supported by NSF (IOS-1257732).

78.2 HEALY, TM*; BRENNAN, RS; WHITEHEAD, A; SCHULTE, PM; Univ. of British Columbia, Univ. of California, Davis; *healy@zoology.ubc.ca*

Contrasting Patterns of Latitudinal Variation in Thermal and Hypoxia Tolerance in Atlantic Killifish

Associations among traits can influence the rates of organismal responses to climate change, which is altering multiple abiotic variables in aquatic habitats, including temperature and oxygenation. As both high temperatures and hypoxia limit the capacity to maintain aerobic metabolic balance, it has been hypothesized that a mechanistic association between upper thermal tolerance limits and hypoxia tolerance limits may be a common feature of aquatic vertebrates. We have tested the predictions of this hypothesis using Atlantic killifish, *Fundulus heteroclitus*. Populations of this species are distributed along the east coast of North America, and northern and southern populations are genetically and physiologically distinct. Southern fish have greater tolerances of high temperatures and hypoxia than northern fish, consistent with a positive association between these traits. However, this pattern could also be due to independent divergence of each trait between the subspecies. To distinguish these alternatives, we measured the thermal and hypoxia tolerances of killifish from eight populations along the coast, including populations located in two contact zones between the subspecies. Thermal tolerance varied linearly with latitude, whereas hypoxia tolerance transitioned sharply from northern to southern values across both contact zones. In addition, no trait correlations were observed within contact zone populations. These results indicate that thermal and hypoxia tolerance limits are unlikely to share underlying mechanistic bases in this species, and that, contrary to prediction, an association between these limits is not a common feature of all aquatic species.

7.2 HEBERT, FO*; GRAMBAUER, S; BARBER, I; LANDRY, CR; AUBIN-HORTH, N; Laval University, University of Leicester; *francois-olivier.gagnon-hebert.1@ulaval.ca*

Major Host Transitions are Modulated Through Transcriptome-Wide Reprograming Events in the Cestode Schistocephalus solidus, a Threespine Stickleback Parasite

Parasites with complex life cycles have developed numerous phenotypic strategies that follow a timeline of developmental events and enable the exploitation of different ecological niches. How these environmental shifts are regulated from a metabolic and physiological standpoint still remain to be fully explained. We examined the transcriptomic response of *Schistocephalus solidus*, a parasite with a complex life cycle, over the course of its development in its intermediate host, the threespine stickleback, and its final avian host. Results from our differential gene expression analysis show major reprogramming events among developmental stages. The final host stage is characterized by a strong activation of reproductive pathways and redox homeostasis. Reaching the infective stage inside the intermediate fish host that precedes sexual maturation in the final host is marked by transcription of genes involved in neural pathways and sensory perception. Our results suggest that un-annotated and *S. solidus*-specific genes could play a determinant role in host-parasite molecular interactions required to complete the parasitic life cycle. Comparative analyses based on such knowledge will help disentangle species-specific patterns of infections from conserved mechanisms, ultimately leading to a better understanding of the evolution of complex life cycles.

P3.243 HEDRICK, BP*; DODSON, P; University of Massachusetts, Amherst, University of Pennsylvania, Philadelphia; *bphedrick1@gmail.com*

Assessing Alligator Limb Architecture Using Geometric Morphometrics: Allometry, Disparity, and Integration

Alligator mississippiensis undergoes an ontogenetic niche shift from a wetland to a riverine habitat and an ontogenetic locomotor shift from terrestriality to swimming. A number of studies have examined ontogenetic scaling of *A. mississippiensis* limbs (using traditional linear morphometrics, scaling of muscle masses, with gait analyses). We further these studies of limb ontogeny by performing a geometric morphometric study of the scapulae, humeri, ilia, and femora of a range of sizes of *A. mississippiensis* (n = 62) in order to examine within-bone allometry, shape disparity between juveniles and adults, and integration between bones. We show that allometry plays a significant role in shape determination in all four of these bones, potentially relating to ontogenetic locomotory transitions. Allometry accounts for a larger component of shape variation in the humeri and femora (>40%) than the scapulae and ilia (<25%) showing that the limb bones are more relevant to the niche transitions than the girdle bones. In all bones, the morphological disparity was higher in the adults than in the juveniles, reflecting broader niche occupation in adults. Our study shows that the scapulae and humeri are more highly integrated than the ilia and femora, contrary to previous studies. Further, the humeri and femora are more integrated with each other than either is with its respective girdle element. The girdles evolved independently relative to the limb bones perhaps because the limb bones are changing in unison through ontogeny in response to the ontogenetic niche shift. This study demonstrates the power of geometric morphometric analyses for providing new insight into a well-understood taxon.

48.6 HEDRICK, TL*; WARRICK, DR; BIEWENER, AA; CRANDELL, KE; TOBALSKE, BW; University of North Carolina at Chapel Hill, Oregon State University, Harvard University, University of Cambridge, University of Montana; *thedrick@bio.unc.edu*

Prey captures by freely behaving barn swallows

Pursuit and interception of moving prey in a 3D environment is a challenging problem nevertheless solved in practice by predators in aquatic, terrestrial and aerial environments. However, the details and sophistication of tracking and intercept strategies little understood and may vary widely based on the biomechanical and sensory capabilities of the species in question. Here we examine aerial predator-prey interactions between barn swallows (*Hirundo rustica*) and insects recorded from wild, freely behaving birds as part of a larger study of swallow field flight behavior and biomechanics. The larger insects recorded here are large and likely not typical barn swallow prey species, but the swallows pursued, intercepted and in the majority of cases some insight may be gained from the results. The prey species in question were not identified but were fast moving, with mean ground speeds of 4.2 to 10.6 m/s; the birds flew at 9.9 m/s and faster. The swallows were foraging low to the ground and prey and swallows were at similar heights; swallows approached in the horizontal and slightly above. The intercept strategy likely varied within even the few available cases since they include a range of visual bearings, a potential constant bearing intercept and others with large changes in visual bearing through the approach. Swallow approaches ranged from behind the prey at a shallow intercept angle to a nearly 90 degree angle after circling from a position well in advance of the insect's path. Response latencies, as determined by cross-correlation of centripetal force, were on the order of 1-2 swallow wingbeats.

83.2 HEERS, A/M*; BARTA, D/E; College of Sequoias, American Museum of Natural History; *ashmheers@gmail.com*

Early behavioral, but late anatomical, maturation in precocial ground birds: form-function relationships during the developmental acquisition of flight

Precocial ground birds fledge and acquire locomotor capacity early in ontogeny, sometimes shortly after hatching. However, anatomical structures used during locomotion appear late in development. For example, Chukar Partridges (*Alectoris chukar*) gain flight capacity approximately 18 to 20 days after hatching, but do not develop adult-like feathers or musculoskeletal apparatuses until two to three months of age. Similarly, Peafowl (*Pavo cristatus*) become flight-capable long before maturation of the flight apparatus. How do immature birds lacking the anatomical specializations of adults achieve adult-like levels of performance so early in ontogeny? Here, we integrate previous work with SIMM modeling (Software for Interactive Musculoskeletal Modeling) and cladistic ontogeny to track the development of locomotor morphology, function, performance, and behavior in precocial ground birds, using chukars as a case study. Our results demonstrate that developing chukars flap and produce aerodynamic forces during wing-assisted incline running (6 to 8 days post hatching) and flight (18 to 20 days post hatching) long before acquiring any of the specialized morphological features characteristic of adult birds (>45 days post hatching). Though younger birds have less aerodynamically effective feathers, less channelized skeletons, and smaller muscles than older birds, they appear to compensate for these limitations with a variety of anatomical and behavioral mechanisms. This complex developmental interplay between different anatomical features and whole body performance highlights the complexity of form-function relationships, and offers new insight into traditional views on the avian body plan and adaptations for flight.

33.6 HEKKALA, ER*; ARDEMA, M; MONTANARI, S; NORELL, M; AMATO, GA; Fordham Univ./AMNH, American Museum of Natural History; *ehekkala@yahoo.com*

Ancient DNA solves the mystery of the extinct horned crocodile from Madagascar

Ancient DNA from a Holocene crocodile specimen of *Voay (Crocodylus) robustus* from Madagascar was used to examine the phylogenetic placement of this species within extant crocodilians. This species was recently separated from Crocodylus and placed in its own genus, *Voay* (Brochu 2007) based on similarities in cranial features shared with genus *Osteolaemus*, the African dwarf crocodile. The species' phylogenetic position is particularly interesting with respect to the recency and circumstances of its extinction, which appears to be coincident with the arrival in Madagascar of both humans and the extant Nile crocodile (*Crocodylus niloticus*). DNA derived from subfossil material was used to create a library for next generation sequencing using whole genome enrichment and sequence capture. A phylogenetic analysis of the mitogenome was used to place the extinct species within the order.

P3.241 HELLIER, RG*; ROBERTSON, JC; Westminster College, PA; *hellrg22@wclive.westminster.edu*

Quantifying Electrosensory Ampullae on the Operculum of Developing Paddlefish

Paddlefish (*Polyodon spathula*) are freshwater, filter-feeding fish with a highly developed electrosensory system that the fish use to interact with their environment. The functional units of electrosensation are ampullae of Lorenzini; these structures occur in large numbers on the head, operculum and rostrum of the paddlefish. In order to assess changes in numbers of ampullae as young fish grow, this study quantifies the number of ampullae specifically on the operculum of several size classes of juvenile paddlefish. Surface pores associated with the ampullae were imaged microscopically after Sudan Black B staining of isolated opercula, and pores were counted using an image analysis program. We predict that the number of ampullae on the operculum, which shows relatively isometric growth relative to the body, will show a lower rate of increase over early growth in comparison to the rostrum, which shows dramatically positive allometric growth. Rostrum ampullae data from a companion study will be used for comparison with opercular counts in similar size-groups of fish. Better understanding of the development of the paddlefish electrosensory system can contribute to greater appreciation for the early life history of this species, which could be significant in conservation efforts.

21.4 HELLMANN, JK; SABOL, AC*; LIGOCKI, IY; HAMILTON, IM; University of Illinois, Urbana-Champaign, University of Michigan, University of California, Davis, Ohio State University; *sabola@umich.edu*

Personality is linked to intragroup social dynamics in a cooperatively breeding fish

Conflict is an inherent part of social life in group-living species. In many species, there is strong selection for group members to manage conflict through the use of submissive and affiliative behaviours, which can stabilize the dominance hierarchy and foster group cohesion. The amount of conflict present in a group, as well as the way in which conflict is managed, likely varies with the personality of the individuals in the group and the extent to which group members are willing to engage in aggressive interactions and to resolve such interactions. To investigate the role of personality in intragroup behavioral interactions, we conducted boldness, aggression, and exploration assays on individual *Neolamprologus pulcher*, a cooperatively breeding fish. We then put these fish into small groups to understand how individual personality influences behavioural dynamics among dominant and subordinate group members. We found that both aggression and exploration/boldness were correlated with interactions among group members. For example, dominant females who scored higher in the mirror-directed aggression trials were less aggressive and more submissive to their mate, whereas dominant male personality was not significantly correlated with his behavioral interactions with other group members. Similarly, subordinates who scored higher in the aggression trials were more submissive to dominants in the group. This suggests that mirror-directed aggression assays may be poor measures of how aggressive individuals actually are within social groups, but instead may measure social competence: socially competent individuals are highly aggressive when interacting against a perfectly matched opponent (i.e. themselves), but more submissive when interacting with dominant individuals.

137.5 HELM, R/R*; MARTíN DíAZ, M/L ; THABET, A/A; TARRANT, A/M; Woods Hole Oceanographic Institution, Woods Hole Oceanographic Institution, Universidad de Cádiz, Woods Hole Oceanographic Institution, Al-Azhar University in Assiut; *rrhelm@gmail.com*

Characterization of peroxiredoxins in the sea anemone Nematostella vectensis

Peroxiredoxins (Prx) are proteins found in all domains of life, and help to mediate the oxidative stress response by binding and neutralizing reactive oxygen species (ROS). To gain insight into Prx evolution and diversification, we first identified Prx sequences in the cnidarian sea anemone *Nematostella vectensis*. We classified these sequences both through construction of a maximum likelihood-based phylogeny and through queries of the PREX Database, which enables subfamily assignment based on structurally relevant motifs. In this way, we identified four bona-fide Prx proteins in *N. vectensis*: Prx4a, Prx4b, Prx5 and Prx6. In contrast to many bilaterians, *N. vectensis* is missing clear homologues to Prx1-3 family members. Like other members of the same subfamilies, Prx4a, Prx4b and Prx 5 contain a catalytic cysteine and a resolving cysteine, while Prx6 contains only the catalytic cysteine. The two Prx4 genes appear to have resulted from a duplication event deep within the cnidarian lineage. Both *N. vectensis* Prx4 genes also contain a deeply conserved cysteine residue that has been shown to undergo circadian cycles of hyperoxidation in diverse organisms. We find potential evidence for subfunctionalization of these two genes in that only Prx4a contains a predicted signal peptide at the amino terminus. Finally, we measured Prx mRNA expression following exposure to elevated temperature, low salinity and hydrogen peroxide, conditions that have been reported to induce Prx genes in a variety of animals. Surprisingly, we did not detect robust upregulation of Prx expression with any of these treatments. This may reflect the high abundance and stability of Prx proteins and their ability to be recycled and reused.

112.2 HENSCHEN, A.E.*; WHITTINGHAM, L.A. ; DUNN, P.O.; Univ. of Wisconsin, Milwaukee; *hensche9@uwm.edu*

Do Plumage Ornaments Signal How Individuals Respond to Stress?

Male ornaments are thought to honestly advertise the physiological quality of potential mates to females. An important aspect of physiological health is stress response, and there is evidence that increased stress can lead to a number of negative consequences, including reduced expression of ornaments. Eumelanin-based (black) ornaments may be particularly susceptible to the negative effects of high stress hormones (glucocorticoids) as increases in glucocorticoids will reduce the production of POMC prohormone, which is modified into peptides that regulate both glucocorticoid and eumelanin production. Thus, males with lower glucocorticoid levels should be able produce larger eumelanin ornaments. We tested this prediction during the breeding season in a population of common yellowthroats (*Geothlypis trichas*), in which the size of the black facial mask is a sexually-selected ornament. Mask size is also positively related to body mass, antibody production, resistance to oxidative stress, and variability at the MHC Class II. We measured stress in males by quantifying both baseline and stress-induced corticosterone (CORT), which is the main stress hormone in birds. Stress-induced CORT was measured 30 minutes after capture. We predicted that males with larger masks would have lower baseline CORT and that their stress-induced increase in CORT would be smaller than males with smaller masks. Although mean stress-induced CORT was significantly higher than baseline levels, the change in CORT was not related to size of the eumelanin mask. This suggests that this plumage ornament does not signal stress response during the breeding season.

22.3 HENSLEY, NM*; FRAWLEY, J; GERRISH, GA; OAKLEY, TH; RIVERS, TJ; University of California, Santa Barbara, Medical College of Wisconsin, University of Wisconsin, La Crosse, University of Kansas; *nikohensley@gmail.com*

Illuminating genotype - phenotype connections in the bioluminescent mating displays of cypridinid ostracods

Since Darwin, diversity in species recognition and mate attraction systems has generated wide interest. However, understanding how such high phenotypic diversity is generated at the molecular level is challenging. To address how differences in mating signals between species are produced, we are studying cypridinid ostracods, which use species-specific bioluminescent displays to attract mates. In ostracods, bioluminescence is produced externally when an enzyme, luciferase, oxidizes the substrate vargulin to produce blue light. These complex patterns vary in many ways, like the duration of each discrete pulse in a train of pulses. But, given their simple genetic basis, they are tractable for connecting genotype to phenotype. Here, we assess the extent to which differences in bioluminescence reflect variation in enzyme sequence. We stimulated light production via mild electric shock from individuals of over 25 species and recorded the pulse decay. We compared these decay rates to luciferase sequences generated from *de novo* transcriptomes in a subset of species, predicting that certain sequence changes are correlated with shifts in decay. First, we found significant variation in both decay rates and enzymes between species. We also found that a small number of sequence changes are associated with divergent phenotypes. Future work will address both the molecular basis of enzyme differences, and if phenotypic differences elicit alternative mating decisions in display receivers. Together, these data help us assess how specific genetic changes contribute to differences in complex signaling behaviors between species.

P1.132 HENSON, JR*; SIMS, CG; SCHOECH, SJ; Univ. of Memphis, Univ. of Arkansas Monticello; *jrhenson@memphis.edu*

Mallards regulate stress responsiveness according to energetic demands

Waterfowl face a multitude of stressors throughout their annual cycles. These stressors include energetic demands associated with life history stage, weather, and waterfowl hunting seasons. Many studies have examined the effects of hunting, but few have focused on how hunting affects the stress physiology of waterfowl. Any stressful stimulus will elicit a physiologic stress response and activate the sympatho-adrenal system culminating with the release of epinephrine and corticosterone (CORT). These hormones aid in survival and recovery over the short-term, but if CORT is elevated over a long period it can lead to decrements in health. Importantly, maintenance of body condition is well known to affect future reproductive potential. The aim of this ongoing study is to determine whether hunting alters body condition (BC) and stress physiology of mallards (*Anas platyrhynchos*). Our recent findings suggest that hunting does not alter BC or baseline CORT. Thus this study focuses on how mallards protect themselves against reoccurring stressful encounters and elevated energetic demands. Mallards may alleviate this is by seasonally altering how they respond to stress. To examine this, we collected mallards before the hunting season in North Dakota and; before, during, and after the hunting season in Arkansas. Birds underwent a standard capture and restraint protocol and blood samples were analyzed for CORT levels. We hypothesized stress induced CORT levels change depending on the energetic demands of annual cycles. Thus far, our data support this and indicate that mallards dampen their CORT response during the fall to minimize decrements in BC.

106.1 HERAS, J*; CHAKRABORTY, M; EMERSON, JJ; GERMAN, DP; Univ. of California, Irvine; *herasj@uci.edu*

The Monkeyface Prickleback (Cebidichthys violaceus) Genome: A Source for Understanding Biology in a Complex Environment

We sequenced the genome of the intertidal, herbivorous fish, *Cebidichthys violaceus* (Teleostei: Stichaeidae) to elucidate the genetic underpinnings of dietary specialization and intertidal existence in this species. *C. violaceus* is part of a phylogeny that showed independent intertidal invasion and evolution of herbivory in comparison to other herbivorous stichaeids (e.g., *Xiphister mucosus*). A juvenile individual collected from San Simeon, California was used to sequence the *C. violaceus* genome, and the genome was generated with Illumina and Pacific Biosciences (PacBio) datasets with 107X and 37X coverage, respectively. From our genomic datasets, we conducted a de novo assembly of the Illumina reads and then a hybrid assembly with both Illumina and PacBio datasets. We estimated the genome to be 526,436,767 base pairs with a N50 contig size of 6.7 Mb. In conjunction, we generated RNA-Seq data from nine tissue types (brain, gill, gonads, heart, liver, mid intestine, proximal intestine, pyloric caeca, and spleen) for annotation of the genome. We are using our transcriptomic data sets to better understand the multitude of processes that allow a fish to be herbivorous and to tolerate the vagaries of intertidal existence (e.g., temperature fluxes, and breathing water and air). Moreover, what we learn from *C. violaceus* will be used to inform analyses of other fishes in the family Stichaeidae, which features dietary diversity, ontogenetic dietary shifts (including a shift from carnivory to herbivory in *C. violaceus* and other taxa), and large biogeographic ranges spanning the eastern and western Pacific Ocean.

S9.11 HERB, Brian R.; Johns Hopkins University; *brianherb@gmail.com*

Epigenetic basis of development of social behaviors in honeybees

Social insects have the incredible ability to produce behaviorally distinct individuals that work together in an interdependent manner. Although many species have achieved sociality throughout evolution, recent studies have not identified a common genetic path to sociality. A key hallmark of social insects is their ability to flexibly shift between tasks according to the needs of the group. In honeybees, workers first assume nursing tasks, and then transition into foraging tasks later in life. This transition is in part dictated by the complex mixture of social cues within the hive that subtly influence worker bees. Epigenetic mechanisms provide a flexible means of transcriptional control that can be responsive to external stimuli. In particular, the epigenetic mark DNA methylation has been shown to assist in worker transitions in honeybee and may assist in phenotype development in other social insects. Since social insects lack a common genetic path to sociality, but do maintain epigenetic machinery, a survey of DNA methylation patterns across social insects was performed. Through the comparison of syntenic regions, gene targets of DNA methylation were compared across social species to identify conserved uses of epigenetic regulation.

S4.8 HEREFORD, J; Univ. of California, Davis; *jhereford@ucdavis.edu*

Physiological and phenological correlates of the seasonal niche in a C3-C4 intermediate

Niche breadth results from physiological and phenological expression. The seasonal niche describes the time of year that an organism is expected to grow and reproduce. I quantified seasonal niche breadth and physiological correlates of the seasonal niche in a short-lived C3-C4 intermediate annual plant. Niche breadth was estimated by quantifying the extent of spatial and temporal variation in performance. Niche breadth was then compared to physiological and phenological variation to determine how variation in physiological tolerance contributes to variation in seasonal niche breadth.

117.4 HERNANDEZ, LP*; BRAINERD, EL; George Washington University, Brown University; *phernand@gwu.edu*

Flexibility in cranial kinematics facilitates surface feeding in a bottom-feeding cypriniform fish, Carassius auratus

Goldfish, cypriniform generalists, are well-equipped for bottom-feeding given both a ventrally-directed mouth and palatal organ for sorting detritus. As bottom feeders goldfish likely represent the basal condition for this clade, however cypriniforms have radiated into a number of ecological niches. While a great many cypriniforms have remained benthic feeders, many have secondarily adopted filter and surface feeding. The ability to feed efficiently within a diverse number of ecological niches has allowed this group to thrive. Using XROMM we have examined the kinematics of suction feeding at the surface versus along the bottom. Although the prey types were not significantly different, goldfish showed significant differences in kinematic profiles when feeding from these two different positions. Neurocranial elevation, in particular showed patterns that were not clearly consistent with prey position. While attacks on the surface showed that gape and neurocranial elevation were synched, these movements were not synched during benthic feeding. The extent of gape was not consistently correlated to the degree of neurocranial elevation. Importantly strikes directed at the bottom were often preceded by a ventral rotation of the neurocranium, a movement not previously noted that would have been nearly impossible to characterize without the use of XROMM. Precise movements of the premaxilla depend on location of prey, suggesting that cypriniforms have substantial flexibility in positioning their mouths during premaxillary protrusion. We suggest that the complexity associated with increased numbers of linkages in the head adds to the potential flexibility in feeding kinematics. This would be particularly important in opening up feeding niches early during the radiation of this group.

118.1 HERNANDEZ, A.V*; GERVAIS, C.R.; RUMMER, J.L.; PORTER, M.P.; Florida Atlantic University, Boca Raton, FL 33431, Macquarie University, Sydney, NSW, Australia 2109, ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD, Australia 4811; *ahernandez2013@fau.edu*

Life history matters: swimming and aquatic walking kinematics of epaulette sharks

The transition from swimming to walking was an important event in the evolution of tetrapods. Many extant aquatic and semi-aquatic species have been studied to understand the adaptions resulting from changes in environmental conditions. For example, epaulette sharks (*Hemiscyllium ocellatum*) have been noted to develop abnormal coloration and patterns during early development following exposure to elevated temperatures. Aquatic locomotion in this species has been categorized into three gaits: slow-to-medium walking, fast walking, and swimming. Here, we described kinematic differences between neonate (n=6) and juvenile (n=6) sharks hatched and reared in the laboratory. Neonates retain nutrition from an internal yolk while juveniles forage for worms, crustaceans, and small fishes. We hypothesized that changes in diet and feeding habits would affect gait performance between neonates and juveniles. Using video tracking software, we examined movement from 13 anatomical landmarks along the fins, girdles, and body mid-line. We calculated kinematic variables to identify characteristic movements and quantify coordination of the different gaits for each shark. Neonates and juveniles differed in a variety of kinematic variables. Notably, the juveniles were more coordinated in their movements. This study provides information about the impact of life history stage on aquatic locomotor performance in epaulette sharks. With a baseline understanding of regular locomotion patterns in this species, we can further investigate how environmental perturbations and climate change could alter their locomotion.

6.1 HERNANDEZ, A. M. *; RYAN, J. F.; University of Florida ; *ahernandez6@ufl.edu*

A preponderance of enzymes in the horizontally transferred genes of animals: evidence from the ctenophore Mnemiopsis leidyi

Horizontal gene transfer (HGT) is the transfer of genes from the genome of one species to that of another. HGT has been documented in several animal species, and recent work has suggested that HGT may have played an important role in the adaptive evolution of particular animal lineages. Despite the remarkability of HGT in animals, relatively little consideration has been paid to global patterns of function in animal HGTs. Likewise, the methodology behind HGT-detection in animals has not been analyzed in depth. Here we present alien_index, a program and database, which automates and standardizes identification of HGTs using established BLAST-based methods. We use alien_index to identify 37 new potential HGTs in the ctenophore (comb jelly) *Mnemiopsis leidyi* and apply phylogenetic and nucleotide-content analyses to support these predictions. All *M. leidyi* HGTs appear in the genomes and transcriptomes of two disparate populations ensuring that these genes are transcribed and unlikely to be contaminants. Furthermore, all *M. leidyi* HGTs are located on scaffolds with other intron-containing genes and 73% have introns. After casually observing a preponderance of enzymes represented in *M. leidyi* HGTs, we used alien_index to identify HGTs in the rotifer, tardigrade, and sponge genomes, and applied a Monte Carlo simulation approach (sampling well-annotated bacterial genomes) to see if enzyme representation was significantly different in these animal HGTs. Enzyme proportions in bacterial genomes significantly differed from animal HGTs, suggesting that there is preferential horizontal transmission of enzymes, or maintenance of enzymes after horizontal transmission. These results are the first to implicate horizontal gene transfer in ctenophores, and more generally, provide insight into how animals integrate alien genes into their genomes.

42.2 HERNDON, CJ*; UZELAC, I; ASTLEY, HC; FENTON, FH; Georgia Institute of Technology, University of Akron; *co.herndon@gmail.com*

Voltage and calcium dynamics in alligator hearts in comparison to mammals

American alligator hearts, despite having four chambers like birds and mammals and unlike most reptiles which have three, have not been well studied. In fact there is no literature about alligator heart action potential or calcium transient. Furthermore, although alligators live in a range of temperatures from 10°C to 30°C, little is known about the effect of temperature on their cardiac electrophysiology. With simultaneous voltage and calcium optical mapping at a resolution of 128x128 pixels and 500Hz, we present here the first detailed study of voltage and calcium dynamics in alligator hearts. Six Langendorff isolated alligator hearts were held at 20°C and 30°C and electrically stimulated. Surprisingly, we found that the action potential duration (APD) did not change much in comparison to mammalian hearts (e.g., rabbits and dogs) with varying temperature. Although we observed more pronounced dispersion of APD across the heart's surface in comparison to mammalian hearts, we also observed less pronounced period doubling bifurcation in voltage and calcium dynamics at fast pacing cycle lengths. Our results indicate that alligators are well equipped to withstand large changes in body temperature without adverse effects in their electrical dynamics that could result in arrhythmia initiation.

99.7 HERREL, A*; LOUPPE, V; SIMURINA, T; PADILLA, P; MOUREAUX, C; MIKAELOFF, F; CLAQUIN, M; COURANT, J; CNRS/MNHN; *anthony.herrel@mnhn.fr*

The evolution of locomotor performance in an invasive amphibian, Xenopus laevis.

Xenopus laevis is a globally invasive amphibian that has been suggested to negatively impact local populations of amphibians and other aquatic vertebrates. As such the modeling of its future distribution is of critical importance. However, classic species distribution models that do not incorporate information on the physiology of the species of interest often largely overestimate potential ranges. As such data on locomotor physiology and its dependence on temperature is essential. In addition, in other invasive anurans it has been noted that animals on the range edge are better performers than those in the center of the distribution, information essential to incorporate in distribution models. Here we provide data on the thermal dependence of two types of locomotor performance traits: jumping performance and terrestrial locomotor endurance in *X. laevis*. Moreover, we provide data on the critical thermal maxima and minima for individuals of this population. Finally we compare endurance capacity and basal metabolic rate for animals from the center and the periphery of the range. Our results show that different locomotor traits have different thermal optima with optima for burst performance traits being higher than those for endurance capacity. Moreover, we find differences in endurance capacity and limb morphology for animals from the center versus the periphery of the range. These data shed new light on the evolution of locomotor performance in a globally invasive largely aquatic anuran.

59.1 HERRERA, MJ*; HERAS, J; GERMAN, DP; University of California, Irvine; *mjherre1@uci.edu*

Digestive Specialization in the Family Stichaeidae: Molecular Underpinnings and Potential for Plasticity

Dietary specialization is best investigated from the molecular to the whole organism level. Prickleback fishes (family Stichaeidae) are an excellent study system in which to study dietary specialization because they exhibit dietary variation in sympatric species, sister taxa with different diets, and feature convergent evolution of herbivory. The objective of this study was to determine the plasticity of prickleback gut length in response to dietary shifts and the genetic underpinnings of dietary specialization. We studied four species that naturally vary in diets: *Xiphister mucosus* (herbivore), *Xiphister atropurpureus* (omnivore), *Phytichthys chirus* (omnivore), and *Anoplarchus purpurescens* (carnivore). We assigned individuals of *X. mucosus* and *A. purpurescens* to omnivore or carnivore diets in the laboratory, whereas *X. atropurpureus* and *P. chirus* individuals were fed the carnivore diet. In wild fish, we observed the longest guts in herbivores, followed by omnivores and then carnivores. Similar effects of diet on gut length were observed in the laboratory-fed fish (omnivore > carnivore within a species). The transcriptomic profiles of pancreatic and mid intestinal tissues of wild-caught and captive fishes were examined using Illumina platforms. Genome-guided transcriptomic assemblies were performed with the reference genome of the prickleback *Cebidichthys violaceus*. We obtained of 16-20 million reads per tissue and analyses of differential expression and enrichment of genes involved in digestion and absorption of nutrients are underway. Overall, this study, will provide crucial insight into how vertebrates specialize to use specific resources, and how plastic the digestive system can be.

P3.29 HERSH, KN*; CAUGHRON, JE; CAUGHRON, JJ; DAVIS, JE; Radford University; *Khersh@radford.edu*

Sangre de Drago Inhibits Growth of Staphylococcal Isolates

The purpose of this research is to expand our knowledge of antimicrobial properties of *Croton lechleri* (commonly known as Sangre de Drago), a tree that grows in the upper Amazon specifically in Peru, Columbia, and Ecuador. By testing its sap, which has been proven previously to be nontoxic, in terms of it's ability to kill arbitrary skin microbiota. Cultural research reveals that Sangre de Drago is frequently used by the native population as a remedy for common skin infections. Bacterial samples were collected from the hands of team participants following a day of research activities in the Amazon rainforest. These bacterial samples were then challenged with sap of *Croton lechleri* during the incubation phase on nutrient agar medium. A zone of inhibition was observed within the test area of *Croton lechleri* sap. The bacterial isolates from the agar plates were positively identified as staphylococcal strains through gram staining. Additional tests were run against known staphylococcal species using sap that was purchased in market in Puerto Maldonado to further investigate bactericidal activity of *Croton lechleri in vitro*. Further research is needed to characterize the precise mechanism of this bactericidal activity.

104.7 HERSH, T; DIMOND, A; RUTH, B; LUPICA-NOWLIN, N; BUTTNER, J; KING, B; LUTTON, B*; Dalhousie University, Endicott College, Brown University, Salem State University, Mount Desert Island Biological Laboratory; *bram.lutton@gmail.com*

Leukocyte Mobilization in Leucoraja erinacea

Through the decades of bone marrow transplantation research, understanding hematopoietic stem cell (HSC) activation and leukocyte mobilization into the bloodstream has been imperative to investigators trying to manipulate these mechanisms and control the production of blood cells from donors, known as hematopoiesis. The little skate (*Leucoraja erinacea*) may serve a unique role in these studies as it lacks an endosteal (i.e., composed of bone) hematopoietic niche, such as that housing mammalian bone marrow. While this compartmentalization is protective in mammals, it is an obstructive barrier for studies of transplantation immunology. *L. erinacea* possesses specialized tissues (the Leydig and epigonal organs), similar in function to mammalian bone marrow but uniquely composed of only the vascular niche; it is within these organs that HSC are maintained. While many molecular and cellular interactions modulate hematopoiesis, the chemokine receptor-ligand pair, CXCR4-CXCL12, is known to play a critical role in homing of HSC for cellular transplant engraftment, as well as maintenance of homeostasis in the bone marrow. Thus, inhibiting this connection with clinical agents, such as AMD3100, a CXCR4 antagonist, activates HSC. We have identified and annotated CXCR4 and CXCL12 expression in *L. erinacea* using genomic and transcriptomic sequence information from the North East Cyberinfrastructure Consortium, available at Skatebase.org. In addition, *L. erinacea* treated with AMD3100 exhibited significant leukocyte mobilization, as assessed by serological methods. Therefore, important implications exist for the L. erinacea model in studies of transplantation physiology and potential therapies for hematological diseases.

133.1 HERTZLER, PL; Central Michigan University; *hertz1pl@cmich.edu*

Development of Muscle and Germ Line in Penaeid Shrimp

Penaeid shrimp embryos develop by holoblastic cleavage to the 32-cell stage, when gastrulation is initiated by the ingression of two mesendoblasts, followed by invagination of nine naupliar mesoderm cells. The naupliar mesoderm cells give rise to the muscles of the first three pairs of head appendages - first and second antennae and mandibles. These dorsal and ventral appendage muscles produce the swimming movements of the nauplius larva. The ventral mesendoblast divides to produce the primordial mesoteloblast, which forms the posterior (teloblastic) mesoderm, and the primordial germ cell. The teloblastic mesoderm forms most of the mesoderm of the cephalothorax and abdomen. The muscles of the cephalothorax form during the late naupliar and protozoeal larval stages. A complex network of abdominal muscles develops through the third protozoeal and mysis larval stages to form the adult pattern in the postlarva. Two sets of developmental transcriptomes have recently been published, which have identified many developmental genes of interest in penaeid shrimp. Penaeid shrimp orthologs of genes hypothesized to be involved in mesoderm/muscle development (*twist*, *snail*, *mef2*, *brachyury*) and germ line (*vasa*, *nanos*, *pumilio*) were found. *twist* and *snail* are expressed from the limb bud stage embryo to the postlarva; *mef2* is expressed from egg to postlarva, and *brachyury* is expressed only during gastrulation. A large RNA-rich granule is inherited by one of the mesendoblasts and may contain germ line determinants. By TEM, the granule contains smaller electron-dense granules, as well as mitochondria and multi-vesicular bodies. The function of selected mesoderm and germ line genes will be tested by RNA interference experiments. The results may yield insights into the evolution of development in decapod crustaceans and could be applied to shrimp aquaculture.

4.1 HESSEL, AL*; NISHIKAWA, KC; Northern Arizona University; *alh385@nau.edu*

Optimal muscle length is the same for twitch and tetanic contractions in muscles from mdm mice: a role for titin in isometric force production?

The muscular dystrophy with myositis (mdm) mutation in mouse is a spontaneous deletion in the I-band portion of the titin gene. I-band titin is elastic and connects myosin to the Z-disk. Mechanical tests of mdm muscles and myofibrils during stretch demonstrate that residual force enhancement is reduced, suggesting a critical role for titin during eccentric contraction. From this line of research, a new mechanism of muscle contraction, the winding filament hypothesis (WFH), was proposed. The WFH adds a role for titin into the sliding filament theory and predicts that during muscle activation, titin binds to and winds upon the thin filaments. The hypothesis suggests that titin stiffness is increased both by titin winding due to cross bridge rotation of the thin filaments and by external forces that stretch the sarcomere. It remains unclear why mdm muscles exhibit reduced isometric stress. We used twitch and tetanic contractions in wildtype and mdm muscles to characterize the length dependence of isometric force production. Results show that decreased isometric stress in mdm is muscle-specific, and that mdm muscles produce maximum force at the same length during twitch and tetanic stimulation. In contrast, it is well documented that maximum tetanic stress is produced at a shorter muscle length than maximal twitch stress in wild-type muscles. Under the WFH, the twitch contraction would lead to titin binding but not allow time for complete winding, and thus would produce a compliant titin compared to a tetanic contraction. The longer optimal length for twitch suggests a that titin stiffness may contribute to active force production. However, if mdm titin fails to bind to thin filaments, then titin stiffness should be similar and both contractions would thus have similar optimal lengths.

51.4 HICKS, JJ*; BELABUT, DM; ALGAR, AC; University of Nottingham, UK, Universiti of Malaya;
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Plantations Induce Ecological Niche Shifts in a Tropical Lizard

The rapid modification of habitats worldwide represents a key challenge to species. In the recent literature much focus has been placed on the effects of rising temperatures, especially for tropical species. However, even rapid climate-induced temperature rises are predicted to occur over a relatively long time scale in contrast to land use changes which can alter microhabitats and corresponding microclimates completely in a single generation. In this study we test whether species can shift their ecological niche to utilize rubber and oil palm plantations in Southeast Asia. We focus on the generalist lizard, *Calotes emma* and two ecological niche axes: thermal and structural. We found that *C. emma* shifts its structural niche in plantation habitats, with coincident differences in ecomorphology (leg length) between habitats. In contrast, we found no evidence of thermal niche shifts, possibly because thermal differences between plantations and forest edges still fall within the temperature preferences of *C. emma* and do not approach it's thermal maximum. Our data suggests *C. emma* may be a rare example of a species that is not only capable of altering its behaviour to survive in plantation habitats but that these habitats are actually more favourable for it than its ancestral forest edge habitat. However the fact remains that this was the only agamid species detected in oil palm plantations in our study area and by far the most abundant of four species in rubber plantation; a shift of low abundance/high species diversity in forests to high abundance/low species diversity in plantations.

P1.280 HIDALGO, F*; MUNOZ, E; BHARDWAJ, E; SHAIK, M; BERG, O; MULLER, UK; California State University Fresno;
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Comparing the suction flow of bladderwort across species to explore the effect of trap size and morphology

Bladderwort are among the smallest suction feeders, with both terrestrial and aquatic species trapping microscopic prey in underwater traps or underground traps in waterlogged soils. In this study we compare the suction performance of a small terrestrial species (*Utricularia praelonga*), a small aquatic species (*U. gibba*), and a large aquatic species (*U. vulgaris*). Our studies of *U. gibba* and *U. vulgaris* show, despite their small size, bladderwort traps feed in the inviscid flow regime: the flow in front of their mouths is predicted by inviscid suction models, the flow in their mouths by the unsteady Bernoulli equation. Maximum flow speeds are 5 m/s in *U. gibba* and 2 m/s in *U. praelonga*, two species with similar-sized traps (diameter 0.7 to 1.4 mm) but very different gape morphologies. Mouth morphology varies widely across our three species. While *U. vulgaris* has its trap door very close to the outer wall of the trap, *U. gibba*'s trap door is shielded by a vestibule. Both these aquatic species have few bristles around their mouth opening, while the mouth opening in the terrestrial *U. praelonga* is shielded by dense clusters of bristles. Our flow data show that the suction flows of these species all develop a central jet in the mouth, but differ in the inflow. For example, we observed several incidences of the *U. praelonga* flow forming a pulsed jet soon after the jet enters the main bladder, in contrast to the steady jet of *U. gibba*. We will explore the causes of these similarities and differences in the future using a robotic model of the traps.

P2.203 HIGGINS, D. J.*; KIRKTON, S. D.; WATERS, J. S. ; Providence College, Union College; *dhiggin2@friars.providence.edu*

The Secret Societies Living Within an Acorn: Temnothorax Ant Colonies Visualized with X-ray Microtomography

Millions of acorns and hickory nuts fall to the ground every year, seeds that may one day give life to a new tree or perhaps fuel the hibernation of a foraging squirrel. Few people however, realize that acorns are also host to a wide range of ecological dynamics. Parasitized by insects including wasps, moths, and beetles, the fruit of these seeds may feed the growth of many different larvae, the feeding-behavior of which contributes to the hollowing out of an internal cavity. This cavity, deserted after the larvae mature, and the entrance or exit hole associated with the insect who was responsible for its construction, may become a home for many different soil dwelling invertebrates and is an especially preferred nest site for a number of species of ants including Temnothorax, Leptothorax, and Myrmica. Due to their tempo, convenient collection, and small to moderate colony sizes, the acorn ants, including *T. curvispinosus*, *T. longispinosus*, and *T. americanus*, also happen to be important model organisms for studying collective behavior and decision making. Acorns with *T. curvispinosus* colonies inside were collected in Rhode Island and visualized with x-ray microtomography. After being submersed in liquid nitrogen, the acorns were warmed to room temperature and mounted for scanning in a SkyScan 1272 (Bruker) micro CT. The acorns were scanned with resolution of 17-26 microns. Projection x-ray images were reconstructed using NRecon software (Bruker) and volume data subsequently analyzed using ImageVis3D and Seg3D (NIH/NIGMS Center for Integrative Biomedical Computing). This research was funded in part by NSF Award Number 1531850 to SDK.

99.4 HIGHAM, TE*; JAGNANDAN, K; SMITH, S; JAMNICZKY, HA; ROGERS, SM; Univ. of California, Riverside, Univ. of Calgary, Univ. of Calgary; *thigham@ucr.edu*

The dynamics of suction feeding among marine and freshwater populations of threespine stickleback, Gasterosteus aculeatus: linking kinematics and geometric morphometrics

Locomotion and feeding are key axes of diversity among fishes, and these are commonly integrated for successful prey capture. Consequently, aspects of predator-prey interactions are likely key drivers of decreased fitness of hybrids and migrants in divergent populations, ultimately playing a large role in ecological speciation. However, little is known about biomechanical variation among highly divergent populations of fishes, or how hybrids function in relation to the original populations. Threespine stickleback, *Gasterosteus aculeatus*, is an ideal species for teasing apart the intricate relationships between ecology, form, and function given the numerous independent invasions of freshwater lakes and streams from a marine ancestor. These natural replicates afford the opportunity to isolate convergence and many-to-one mapping of form to function. We investigated the differences in suction feeding kinematics and ram speed in 30 individuals from the west coast of British Columbia spanning freshwater, marine, and hybrid (marine x freshwater) individuals. This included both wild-caught fish and lab crosses. Feeding sequences were obtained using a high-speed camera (500 fps), and micro CT was used to link differences in kinematics with three-dimensional geometric morphometrics. From this, we can determine if there is concordance or a mismatch between morphology and biomechanics. Finally, we discuss the importance of these data for informing patterns of reproductive isolation and ecological speciation.

P1.270 HIGHTOWER, BJ*; INGERSOLL, R; CHIN, DD; LAWHON, C; HASELSTEINER, AF; LENTINK, D; Stanford University; *bhightow@stanford.edu*

Design and Analysis of Aerodynamic Force Platforms for Free Flight Studies

We describe and characterize the design of the aerodynamic force platform (AFP), a new system that can directly measure the aerodynamic forces generated by freely flying animals and robots. It is essential to be able to take *in vivo* recordings in freely flying animals to better understand the precise aerodynamic function of their flapping wings, in particular the differences between the downstroke versus the upstroke. The AFP is the first device that allows the direct measurement of these forces during free flight. It is designed to be stiff yet lightweight, with the structural vibrations characterized such that the measurements we take are not occluded by the natural frequencies of the structure. To ensure the system has the highest possible natural frequency and can accurately measure the fluid mechanic forces generated by freely locomoting birds, bats, and robots, careful consideration of the design of the support truss, force plate, window, contact point, and custom force sensors must be made. Notwithstanding the broad range of applications, the immediate opportunity to perform high-throughput, real-time, non-intrusive, and *in vivo* comparative biomechanics analysis of force generation by locomoting animals - including complex bimodal terrestrial, aquatic and aerial behaviors - will help advance the field of experimental biology.

P1.240 HIJAZI, T*; STAYTON, CT; Bucknell University; *th019@bucknell.edu*

Can Common Morphological Proxies for Drag Accurately Predict the Hydrodynamic Performance of Turtle Shells?

Hydrodynamic performance is an important factor in the living and non-living realms, and has been actively studied across many domains ranging from the swimming of living organisms to the propulsion of aircrafts and airfoils. Because of the difficulty inherent in measuring hydrodynamic factors (such as drag coefficients) or performance directly, biological studies often use morphological proxies to measure such hydrodynamic performance. Unfortunately, the utility and accuracy of many of these proxies have yet to be validated for many species. Turtle shells may be used as a model system to study hydrodynamic behavior and assess the ability of such proxies to successfully measure hydrodynamic drag. We designed and printed multiple three-dimensional models shells, corresponding to the major axes of variation among turtle shells. We then measured drag on these shell models in the Bucknell University wind tunnel, and used regression to analyze the relationships between the measured drag coefficients and various proxies which have been proposed for hydrodynamic performance. Our preliminary analyses showed that none of the given proxies accurately predict changes in the drag coefficient among variously shaped model shells. It is therefore possible that the usage of such common proxies does not provide useful information concerning hydrodynamic performance in organisms. Further research regarding the relationship between hydrodynamic performance and more complex, possibly organism-specific, aspects of shape may allow us to develop more accurate predictors of drag.

30.7 HILL, JJ *; DONOGHUE, PCJ; RAYFIELD, ER; University of Bristol, Bristol, UK; *jjhill100@gmail.com*

Evolution of Lower Jaw Disparity: During the Initial Radiation of Gnathostomes

The lower jaw is an important proxy of feeding ecology. Transformations in mandibular shape and structure may have facilitated the emergence of different feeding behaviors such as the transition from ram, filter, and rake feeding to suction and protrusion feeding. Here we present an outline and elliptical Fourier analysis of modern and Paleozoic aquatic jawed vertebrates to characterize jaw shape disparity. We achieve this via an exploration of lower jaw morphospace and an evaluation of the functional and ecological consequences of lower jaw shape variation. 95% of shape variation is summarized on seven axes and all component clades of early gnathostomes exhibit overlapping morphological variation to some degree. We find that Modern faunas are more disparate than fossil faunas largely due to variation in extant actinopterygian mandible shape. Our results reject the early burst model of clade evolution and contradict the statement that maximum disparity is reached early in gnathostome evolutionary history. We also find that only some ecological niches that were vacated by fossil taxa have been convergently refilled with living taxa; therefore suggesting the possibility that other factors besides function affect lower jaw morphospace occupation.

11.5 HILL, GE*; LOPES, RJ; JOHNSON, JD; TOOMEY, MB; FERREIRA, M; MELO-FERREIRA, J; ANDERSSON, L; CORBO, JC; CARNEIRO, M; HILL, Geoffr; Auburn Univ., Universidade do Porto, Wash U St Louis, Uppsala Univ.; *ghill@auburn.edu*

Genetic Basis for Red Coloration in Birds

One of the best-studied ornamental traits is carotenoid-based coloration. In many bird species, red coloration is a criterion in female mate choice with females choosing males with red-shifted as opposed to yellow-shifted hue. Few bird species ingest red carotenoid pigments. To produce red feather coloration, most birds ingest yellow carotenoid pigments and biochemically convert them to red ornamental pigments via an oxidation reaction catalyzed by a previously unknown ketolase. In an effort to identify the ketolase, we conducted a comparative genomic study of the common canary (Serinus canaria) which has only yellow feather coloration, the red siskin (Spinus cucullata) which has red feather coloration, and the "red factor" canary which is a hybrid taxon with red feather coloration produced by crossing common canaries with red siskins. Using whole-genome sequencing, we identified two genomic regions introgressed from red siskins into red factor canaries that are required for red coloration. One of these regions contains a gene encoding a cytochrome P450 enzyme, CYP2J19, which is very likely the ketolase that enables yellow-to-red conversion of carotenoids. Transcriptomic analysis demonstrates that CYP2J19 is significantly upregulated in the skin and liver of red factor canaries and that it is also upregulated in the retina where red carotenoid pigments are also produced. The second introgressed region required for red feathers resides within the epidermal differentiation complex, and we speculate that this gene plays a key role in the incorporation of carotenoid pigments into growing feathers. The discovery of the gene responsible for red carotenoid coloration in birds has important implications for understanding the evolution of ornamental traits and female mating preferences.

P1.197 HILLARD, CJ*; PENNING, DA; MOON, BR; University of Louisiana at Lafayette, Missouri Southern State University; *cjh7032@louisiana.edu*

Quantitative Effects of Body Temperature on Snake Strike Performance: New Insights Into the Elastic-Recoil Hypothesis

For many ectotherms, temperature has a profound effect on performance, such as for the sprint speeds of lizards. However, elastic-recoil mechanisms have allowed other ectotherms to partially circumvent temperature dependence, such as the tongue-projection mechanisms of some salamanders and chameleons. In one paper, pre-strike muscle activation patterns in a viper indicated that striking is driven largely by elastic recoil of the muscle-tendon complex. With elastic-recoil mechanisms being partially independent of temperature, we would expect strike performance in snakes to have low tempen that temperature significantly affects strike performance. Here, we set out to tesrature-dependence under the elastic-recoil hypothesis. However, work on another viper has showt the effects of temperature on defensive strike performance in adult western ratsnakes (*Pantherophis obsoletus*). To do this, we tested each snake at 5 body temperatures (15-35°C) and recorded 3-8 defensive strikes at each temperature using a high-speed camera (250 fps) and Tracker 4.87 software. We analyzed peak performance values for each of four strike variables: maximum strike distance, minimum strike duration, maximum strike velocity, and maximum strike acceleration. We analyzed each strike variable as a dependent variable and the temperature category as the independent variable (repeated measure) in order to characterize the effects of body temperature on strike performance. Changes in temperature significantly affected strike performance in ratsnakes with reduced strike performance at lower temperatures and the highest strike performance at 30°C. The significant and moderate temperature dependence in our results indicates that elastic recoil contributes only mildly, if at all, to strike performance in snakes.

P1.186 HILLENIUS, WJ*; SMITH, TD; REHOREK, SJ; College of Charleston, Slippery Rock University; *hilleniusw@cofc.edu*

Variation in the route of the tetrapod nasolacrimal duct: the long and short of it

The nasolacrimal duct (NLD) connects the orbital region to the nasal cavity in most tetrapods. Traditionally, its primary function is considered to drain "excess" fluids of the orbital glands (e.g. the Harderian and lacrimal glands) away from the cornea. The NLD is generally subdivided into two segments: a caudal part within in a bony canal (consisting variably of the lacrimal and maxillary bones) and a rostral membranous portion within the nasal cavity (i.e., passes within the mucosa of the lateral nasal wall, unenclosed by bone). Although the route of this duct has been described in a variety of tetrapod taxa, less is known about its ontogeny. In rodents and lagomorphs, both parts of the NLD develop comparatively early in ontogeny. The rostral opening of the NLD accompanies the narial region as the nose lengthens, obtaining a fairly straight course. In Laysan Albatross and Alligator, the membranous portion forms a very short segment, as the NLD opens into the nasal cavity soon after emerging from the bony canal, roughly in the center of the nasal cavity. In tarsiers, anthropoid primates, and possibly pigs, both parts are formed but the rostral membranous portion falls apart in the perinatal stages, leaving the caudal portion to open into the central nasal cavity slightly rostral to where it emerges from the bony canal. The bony canal thus appears to be conserved in several tetrapods, whereas the rostral, membranous portion, even when present embryologically, may not be retained postnatally. This variable development of the NLD route appears to be associated with alterations of the ultimate function of the nasolacrimal fluids, and the NLD should probably be regarded as far more highly adaptable organ system than traditionally recognized.

33.1 HILLIARD, JL*; HAJDUK, MM; SCHULZE, A; Texas A&M University Galveston Campus; *jhilliard@tamu.edu*

Delineation of Capitella Species (Annelida: Capitellidae) in the Northern Gulf of Mexico and Floridian Ecoregions

Capitella capitata was frequently cited as a cosmopolitan bioindicator due to its occurrence in high densities in disturbed marine environments. However, it is now clear *C. capitata* is a cryptic species complex on the basis of allozyme and developmental studies. We aimed to assess species boundaries in this complex in the Northern Gulf of Mexico and Floridian Ecoregions using molecular sequence data. We sequenced individuals of *C.* cf. *capitata* and *C.* cf. *aciculata* (distinguished by acicular spines on the first two chaetigers) collected from Texas and Florida Gulf of Mexico coasts and *C.* cf. *caribaeorum* from the species' type locality in Miami, Florida. These data were analyzed in conjunction with data available in GenBank (Canada and Indo-Pacific waters). Our results indicate the presence of a Gulf of Mexico/Florida clade that is distinct from populations in Canada and the Indo-Pacific. Populations are structured geographically, with support for Texas and Florida clades. Within the Florida clade there is support for Gulf of Mexico and Miami (*C.* cf. *caribaeorum*) clades. There are no clear boundaries between *C.* cf. *capitata* and *C.* cf. *aciculata* within the Texas and Gulf of Mexico Florida clades. This is corroborated by the fact that multiple specimens were morphologically intermediate between the two species. Future efforts will be focused on understanding the relationships between these three putative species in the Northern Gulf of Mexico and Floridian Ecoregions.

P1.167 HIZON, B*; STRAND, E; ALVES, S; LANE, J; DENNY, MW; DOWD, WW; Loyola Marymount University, Hopkins Marine Station of Stanford University; *bhizon@lion.lmu.edu*

Effects of acute and chronic salinity changes on thermal tolerance in the tidepool copepod Tigriopus californicus

The copepod *Tigriopus californicus* inhabits dynamic tidepools where multiple environmental factors vary in both a predictable and unpredictable fashion. Our objective was to quantify interactions between salinity and acute thermal tolerance. Copepods collected from Hopkins Marine Station were acclimated in 60ppt or 30ppt salinity for two weeks and then acutely transferred to a range of salinities before exposure to a controlled heat stress. These preliminary data revealed up to a 10°C difference in LT_{50} between the two acclimation salinities when tested at high acute salinities. Opportunistic field sampling of thermal tolerance of mature females corroborated the lab observations. Specifically, initial LT_{50} in egg-bearing females was high when the tide pool salinity exceeded 80ppt; LT_{50} decreased after the salinity stochastically decreased to 37ppt following a wave event. The LT_{50}subsequently increased after the salinity naturally reverted to higher levels over several weeks of evaporative concentration. In a third experiment, mature females were placed in salt water ranging from normal seawater (30ppt) to 60ppt. As the females' offspring hatched and matured, both offspring and parental generation females were subjected to acute heat stress. Both parent females and offspring reared in higher salinities exhibited higher thermal tolerance, substantiating our previous findings. Altogether, copepods exposed to a higher salinity - both chronically and acutely - exhibit compensatory physiological responses that enhance survivability of other acute stressors such as temperature. Such interactions between covarying environmental parameters add complexity to biological forecasts.

P1.180 HLESCIAK, MT*; STAYTON, CT; Bucknell University; *mth015@bucknell.edu*
Analysis of Evolutionary Patterns and Rates of Sexual Size Dimorphism and Sexual Shape Dimorphism in Turtles
We investigated large-scale patterns of the evolution of sexual shape dimorphism (SShD) and sexual size dimorphism (SSD) in turtles, through the following hypotheses: H1) Female and male turtles consistently differ in shape in all turtle species. H2) Female and male turtles show additional differences within certain habitats. H3) Rates of evolution of SSD and SShD vary among turtle families. H4) Rates of evolution of SSD and SShD vary among habitats. These hypotheses were tested using a data set of 53 3-dimensional landmarks digitized at scute triple-junctions of 2397 specimens of 255 turtle species (of which 226 had both males and females). We tested our first hypothesis by creating separate phylomorphospaces for both females and males, and analyzing the differences using phylogenetic MANOVA. We tested the first parts of our third and fourth hypotheses, that rates of evolution of SSD will vary among turtle families and among different habitats, using a Brownian model of rate variation, implemented in the R package phytools. We tested for differences in the rates of SShD evolution using a modification of the compare.evol.rates function in the R package geomorph. There was no evidence of consistent shape differences between females and males across all turtles. SSD in aquatic species evolved significantly faster than in terrestrial species. SSD in aquatic species may evolve faster because of a greater variety of selective pressures that may be encountered in water as opposed to land, or different modes of sexual selection in different environments. The lack of consistent differences between sexes was surprising, but females and males of different species may achieve the same functional result with a variety of different shapes. Future studies will analyze SSD and SShD in turtles of different sizes, latitudes, and ecosystems.

29.7 HODGE, JR*; WAINWRIGHT, PC; University of California, Davis; *jhodge@ucdavis.edu*
The Influence of Sociality and Trophic Niche on Defensive Morphology in Butterflyfishes
Butterflyfishes (Family Chaetodontidae) are iconic coral reef inhabitants. Their beautiful and striking color patterns belie a potent set of structural defenses against predators, featuring an unusually deep-bodied shape and numerous, long and strong spines in the dorsal and anal fins. Both a deep body and spines discourage gape-limited predators. We explored the impact of social grouping and trophic niche on defensive morphology across 97 butterflyfish species. Grouping increases vigilance for predators, while feeding in close proximity to reef structures may keep refuges close at hand. Nine morphological traits that function to defend against, or detect and avoid predation were measured and analyzed in a phylogenetic context. Phylogenetic least squares analysis revealed no relationship between body depth and spine length, as had been found in a survey that spanned teleosts. We found no effect of grouping behavior on defensive morphology. However, we did find a significant trend of shorter spines in more corallivorous species. The decoupling of spine length from body depth suggests that a high body-depth alone may adequately protect most butterflyfish species from gape-limited predators, or they may rely on other sources of protection. The reduction of spine length in coral feeders suggests that their close association with live corals may afford them additional protection from predation, or, shorter spines may facilitate movement in dense coral microhabitats where long spines would catch on coral branches.

P1.6 HODIN, J*; FAUVILLE, G; MILLER, P; EPEL, D; SÄLJÖ, R; DUPONT, S; Friday Harbor Labs, U. of Washington, USA, U. of Gothenburg, Sweden, Hopkins Marine Station of Stanford U., USA, Hopkins Marine Station of Stanford U., USA; *larvador@uw.edu*
I2SEA: Students Envisioning Solutions to Ocean Acidification and Climate Change
The collaborative I2SEA project (Inquiry to Student Environmental Action at i2sea.stanford.edu) is dedicated to promoting climate and ocean literacy in young people. We do so by producing and disseminating a learning resources toolbox including free-to-use, quality hands-on and computer-based learning resources that: inform about climate change and ocean acidification (OA); provide platforms for students to discuss the issues and possible solutions with classmates, experts and peers worldwide; and support personal, school-wide and community actions that put their envisioned solutions into practice. The toolbox includes: *two virtual laboratories on OA, in which students learn about the problem, design and run experiments, gather realistic data, analyse it and discuss it with classmates; *an interactive presentation (with additional ones planned) from project co-PI and OA expert Sam Dupont expands on the virtual labs to consider broader biological, cultural and economic implications of OA and climate change; *our international student carbon footprint calculator, extensively documented and focused on aspects of a students' lifestyle that she has control over; *our communication platform, where students engage in conversations with their peers worldwide to envision solutions to global environmental challenges. In our poster, we will introduce our tools for attendees and discuss plans for upgraded versions and additional tools to be produced in the coming years. We encourage attendees to share our website with classrooms around the world.

105.1 HOEKSTRA, LA*; MITTMAN, E; WEBER, RC; JANZEN, FJ; Iowa State University; *lhoek@iastate.edu*
Continuously-Updated Bayesian Sampling to Aid Estimates of Temperature-Dependent Sex Ratios
Most animals with temperature-dependent sex determination (TSD) are long-lived. Confidently evaluating the compatibility of this unique life-history trait with global climate change thus will likely require decades of data. Unfortunately, given slow maturation to reproductive maturity, sacrificing a portion of offspring is typically required to accurately estimate the cohort sex ratio of populations with TSD. Concerns regarding the impact of such lethal sexing protocols increasingly challenge the justification for long-term investigation of species with TSD. To that end, we provide a modeling framework to estimate the prior probability distribution of clutch sex ratio and to continuously-update beliefs of nest sex ratio during sampling to minimize animal sacrifice.

P1.133 HOFFMAN, AJ*; WADA, H; Auburn University; *ajh0077@tigermail.auburn.edu*

The effects of early stress conditioning on future stress tolerance and fitness-related traits

An organism's environment during development can have effects on phenotype that carry over into adulthood. Developmental stressors are thought to have a negative impact on physiological functions and fitness. However, recent work suggests that a mild developmental stressor can have beneficial effects via preparing the organism to better withstand negative impacts when exposed to high levels of the stressor later in life. We hypothesized that acquired stress tolerance decreases the negative effects of heat stress on fitness-related traits. To test this we exposed zebra finches (*Taeniopygia guttata*) to a prolonged mild heat stress (38° C) as juveniles for 28 days with the prediction that the birds will gain an acquired thermotolerance which will continue into adulthood. As adults the birds were then exposed to a high heat stressor (42° C) for 3 consecutive days and we examined the effects of heat stress on immune function and reproductive performance. More specifically, we measured wound healing rate as a proxy for an overall immune function. To do this, healing rate of a skin excision approximately 3.0 mm in diameter was measured. We predict that birds subjected to the mild heat treatment as juveniles and the high heat as adults will have a comparable rate of wound healing to those of the control-control group, and those that were exposed to the high heat treatment as adults but not conditioned as juveniles are expected to have the slowest wound healing rate. We also tested whether conditioned individuals had higher reproductive performance compared to controls. Following wound healing completion, females were paired with non-experimental males and clutch size and egg mass were measured. We predict that heat conditioned females have a higher clutch size or egg mass compared to controls.

P1.176 HOFFMANN, S*; KRAUSE, DW; HU, Y; NYIT College of Osteopathic Medicine, Old Westbury, Denver Museum of Nature & Science, CO, Stony Brook University, NY; *shoffm04@nyit.edu*

First Postcranial Skeleton of a Gondwanatherian Mammal: Reconstructing Posture and Locomotion

Until recently, the fossil record of the Cretaceous to Paleogene Gondwanatheria almost exclusively consisted of isolated teeth and fragmentary jaws. An undescribed and pristinely preserved skeleton of a gondwanatherian from the Upper Cretaceous Maevarano Formation of Madagascar presents the first opportunity to study the postcranial morphology, posture, and locomotor behavior of these enigmatic early mammals. The specimen belongs to a new genus and species and represents only the fourth taxon known from articulated postcranial material for any Mesozoic mammaliaform from the southern hemisphere. The Malagasy taxon exhibits an unusually high number of trunk vertebrae for mammals (at least 19 rib-bearing/thoracic and 11 non-rib-bearing/lumbar vertebrae). The lumbar vertebrae bear anterolaterally projecting transverse processes and tall spinous processes, and the trunk vertebrae have articular facets that remain coronally oriented. These vertebral features may have facilitated lateral bending of the spine rather than parasagittal movements; in combination with other traits, this may indicate abducted placement of the hind limbs. In contrast, the forelimbs of the new Malagasy mammal exhibit adaptations for a parasagittal posture. The glenoid fossa of the scapula is ventrally oriented, the distal humerus bears a deep humeral trochlea, and the long olecranon of the ulna bends posteriorly. Rotational movements between the ulna and radius appear to have been limited; such a restriction to flexion and extension at the elbow joint was previously unknown for non-therian mammals. How the basal pattern of a sprawling hind limb and seemingly derived, therian-like arrangement of the forelimb might have impacted gait is the subject of ongoing study.

118.4 HOFFMANN, SL*; LEIGH, SC; DONATELLI, CM; BRAINERD, EL; PORTER, ME; Florida Atlantic University, University of California, Irvine, Tufts University, Brown University; *shoffmann2014@fau.edu*

Three-dimensional movements of the pectoral fin during routine turns in the Pacific spiny dogfish, Squalus suckleyi

Early models treated shark pectoral fins as semi-rigid foils, functioning to generate lift and adjust the shark's vertical position in the water column. However, DPIV analysis demonstrated that for at least two species negligible lift is generated during swimming, suggesting that pectoral fins may serve another function. In bonnethead and thresher sharks, pectoral fins have been observed to play a role in turning and braking, respectively. Here we propose that Pacific spiny dogfish, *Squalus suckleyi*, use their pectoral fins when executing turns by rotating with three degrees of freedom about the articulation between the pectoral girdle and the base of the fin. We used Video Reconstruction of Moving Morphology (VROMM) to track rigid body points in 3D and quantify the movement of the pectoral fin in relation to the body. Volitional swimming data were paired with post-mortem electrical stimulation of pectoral girdle muscles to infer how specific kinematic outcomes are produced. We found that during volitional turning, the pectoral fin on the inside of the turn is depressed, protracted, and supinated. Similar depression and supination of the pectoral fin occurred with electrical stimulation of the ventral pterygoideus muscle, and stimulation of the cranial pterygoideus was solely responsible for protraction. We infer that the cranial and ventral pterygoideus muscles produce these pectoral fin movements. This study is the first to use underwater cameras in a large volume tank for VROMM. We propose that with more testing, these or similar cameras may be used in natural environments for VROMM analyses.

S9.9 HOFMANN, Hans A; HOFMANN, Johann; The University of Texas at Austin; *hans@utexas.edu*

Neural and molecular mechanisms of cooperative defense

Cooperative behavior is widespread among animals, yet the neural mechanisms have not been examined in detail. Without knowledge of how the brain processes information during cooperative behavior, our understanding of the role of cognition in cooperation remains limited. We used cooperative territory defense in a cichlid fish to examine neural activity in forebrain regions known for their role in social decision-making. We find that a territorial male neighbor will engage in cooperative defense dependent on the perceived threat of the intruder. Cooperative behavior in this context is processed in the putative homolog of the mammalian basolateral amygdala and in the preoptic area, as well as in preoptic dopaminergic neurons. Further, we find that the resident male modulates his behavior dependent on whether help is received from the neighbor. In the resident, neighbor behavior is correlated with activity in the homolog of the mammalian hippocampus. By delineating the neural activity networks and dopaminergic pathways associated with distinct behavioral roles in a cooperative context, our results lay the foundation for the neurobiological analysis of cooperation within a comparative framework.

S6.3 HOKE, K.L.*; SHIZUKA, D; HEBETS, E.A.; HOKE, Kim; Colorado State University, University of Nebraska Lincoln; *kim.hoke@colostate.edu*

Viewing social behavior through the lens of neural circuitry for target-action selection

We reframe classic views of sensory-motor integration in a communication context within an emerging framework in which target selection and action selection emerge from recursive neural circuits within signal receivers. Nonlinear neurophysiological responses to complex signals define the current set of potential sensory targets, i.e., traits of signalers (target selection). As targets are refined, possible motor responses to those targets are narrowed to a single coherent action (action selection). The immediate context in which an individual perceives the signal, developmental experience of the individual, and evolution of signal receivers all predispose the sensory-motor circuits toward specific targets and action towards those perceived targets. We propose that synergism or interactions among complex signal components at the behavioral level arises from either the combinatory interactions between target-action links with respect to different signal components, or to the hierarchical modulation of target selection, action selection, or learning in which a subset of signal components influence the action response to other signals.

P3.213 HOLDEN, R. A.*; CHEU, A; BERGMANN, P. J.; Clark University; *rholden@clarku.edu*

Performance Variation in Basilisk Lizards During Different Aquatic Modes of Locomotion

Animals need to perform a variety of tasks to survive and reproduce, and they also have a choice of how to perform some of those tasks. Basilisk lizards *(Basiliscus vittatus)* have the ability to both swim through water, and run on its surface. Although we know that these lizards can cross bodies of water using these two different modes of locomotion, it is unknown why they decide whether to run or swim. Many factors could play a role in making this decision, such as cost of locomotion, types of predators in the environment, or maximizing locomotor performance. Variables such as velocity and acceleration can be used to compare performance amongst the two modes of locomotion. The average velocity, maximum velocity, and maximum acceleration were calculated for each of the 2-6 trials for each mode of locomotion and each sampled individual. The fastest trial for each mode of locomotion was compared using paired t-tests. Basilisks attained significantly higher average and maximum velocities while running on water than when swimming. However, maximum acceleration did not differ between the two locomotor modes. These finding showed that the juvenile basilisks that we studied were able to run on water faster than swim through it. Hence, we would expect that they might prefer to run on water, because it would allow them to better escape predators.

55.4 HOLDEN, KG*; GANGLOFF, EJ; BRONIKOWSKI, AM; Iowa State University, Iowa Sate University; *pettinkg@iastate.edu*

Preparing for winter dormancy: Early-life experience affects condition, metabolism, and hormonal response to cold temperatures in the checkered garter snake, Thamnophis marcianus

Characterizing the physiological response to prolonged cold exposure in ectotherms is essential in understanding the maintenance of long-term energy balance. As global climatic patterns continue to change, it becomes increasingly important to quantify the thermal reaction norms of metabolic and hormonal function during periods of hibernation and inactivity. Furthermore, little is known about the drivers of individual variation in physiological responses to sustained cold temperatures. Here we used the checkered garter snake, a widespread ectothermic vertebrate, to test the influence of maternal effects, rearing conditions, and immediate thermal environment on metabolism and physiology during a cooling phase. In this experiment we analyzed the effects of parental nutrition, and developmental thermal regime on thermal response curves of oxygen consumption rate, plasma corticosterone concentration and plasma glucose concentration during a temperature step-down protocol (20, 15, 10, and 5°C) simulating the descent into hibernation followed by an extended period of prolonged hibernation at 5°C. We will discuss these results in the broader context of mechanisms that maintain physiological functionality and survival during seasonal periods of inactivity in a temperate ectotherm.

143.2 HOLMES, IA*; RABOSKY, DL; DAVIS RABOSKY, AR; Univ. of Michigan, Ann Arbor; *iholmes@umich.edu*

Microbial lineages in a squamate host community

We compare 250 bacterial and eukaryotic hind-gut microbiome samples taken from a community of thirty two lizard and snake species in the Chihuahuan desert. We assess the transmission of microbial lineages between hosts, and ask whether microbial lineages are more likely to be shared by hosts that are related phylogenetically. We compare the number of nearest-neighbor lineages shared within as opposed to between host species. If host genome constrains microbiome assembly, we expect to find a greater number of nearest-neighbor microbial lineage connections between conspecific, then congeneric hosts compared to confamilial or more distantly related hosts. As a null hypothesis, we permute microbial lineages across hosts, to determine whether more nearest neighbor links occur between congenerics than would be expected by chance. We test whether diet category influences microbiome by comparing strict insectivores with hosts that prey on vertebrates.

136.1 HOLMES, PD*; SHIA, V; MOORE, TY; VASUDEVAN, R; Univ. of Michigan, Univ. of California, Berkeley; *pdholmes@umich.edu*

Direct perturbation on humans performing sit-to-stand motion reveals corrective feedback control strategy

Animals use feedback to correct for deviations from an ideal motion to improve their accuracy when performing tasks, whether it's plucking a fruit from a tree or maintaining balance while standing from a resting position. Correcting for deviations from an ideal motion can be essential to survival, especially in elderly humans who are often severely injured while failing to successfully perform sit-to-stand (STS) motions. One simple strategy that can be theoretically used to correct trajectories is linear state feedback (LSF), in which linear gains are placed on errors from an ideal trajectory and added back into the motion's nominal control law. To determine whether humans use the LSF strategy to correct their motion, we observed human response to perturbation while performing STS motions. Eleven human subjects were perturbed by pulling them either forward or backward from the waist via motor-driven cables. Perturbations of up to 124 N of force were applied at various times between seat-off and standing. Human motion was quantified using motion capture data, and was modeled as an inverted pendulum. Each subject's perturbed trajectory was compared to their own unperturbed trajectories. We found that corrective movements in response to perturbation fit the LSF strategy. By quantifying the magnitude of perturbation a human can withstand and how effectively they can perform the LSF strategy, this type of perturbative experiment has the potential to identify individuals at risk for debilitating injury. Since the response to perturbation is commonly measured in animal experiments, this approach enables direct comparison between human and other animal control strategies.

P2.65 HOLMQUIST, E*; TULENKO, FJ; KIGUNDU, G; CASS, AN; DAVIS, MC; Kennesaw State University, Monash University; *eholmqui@students.kennesaw.edu*

Fin-folds and autopods share a conserved Shh-Gremlin-Fgf regulatory network

The morphological transition from fins to limbs involved several key changes in appendage anatomy, including the loss of the distal dermal skeleton and an expansion/remodeling of the endoskeleton to form an autopod (hands/feet) with digits. Under most models, fin-folds and autopods are considered non-homologous, patterned by different developmental modules, and composed of different types of bone, despite similar distal positions in the appendage. Here we present gene expression data from a basal actinopterygian, the American paddlefish *Polyodon spathula*, that contributes to a growing body of evidence in support of a shared regulatory homology between fin-folds and autopods. The gene regulatory networks that integrate limb bud outgrowth and patterning have been partially characterized in tetrapods, revealing molecular interactions between the posterior limb bud mesenchyme (i.e., the zone of polarizing activity, ZPA) and the distal limb bud ectoderm (the apical ectodermal ridge, AER). In this network, ZPA-derived *Shh* acts through LIM-homeodomain transcription factors to induce the *Bmp* antagonist *Gremlin*. *Gremlin*, in turn prevents *Bmp* inhibition of AER-derived Fgf's, which maintain ZPA-*Shh*, resulting in a positive regulatory loop that persists through patterning of the digits. Herein, we characterize components of this network in the paired fins of paddlefish and demonstrate an overall pattern similar to that of the autopod. Additionally, we characterize the likely role of Fgf-producing cells of the fin-fold, and use these to test models of fin-fold outgrowth that propose heterochronic shifts in AER signaling that may explain the appendage phenotypes seen in derived lineages.

32.1 HOLOWKA, NB*; BHANDAL, V; LAM, O; THOMPSON, NE; DEMES, B; Harvard University, Stony Brook University Medical Center, NYIT College of Osteopathic Medicine; *nick_holowka@fas.harvard.edu*

Chimpanzee Impact Forces During Walking and Implications for the Evolution of Bipedalism

Humans and great apes are the only primates known to make initial substrate contact with the heel of the foot during walking. This ‘heel strike' foot posture causes high impact peak forces in humans, and some argue that hominins evolved a calcaneus that is more robust than that of great apes to help resist the shock of impact during bipedal walking. However, these forces have not been thoroughly investigated in great apes. We measured impact peak forces at foot strike in three subadult male chimpanzees (avg: 6.1 yrs., 30.9 kg) during bipedal and quadrupedal walking on a flat runway. We found that unlike humans, chimpanzees often make initial contact with the forefoot and midfoot regions instead of the heel during walking, but that foot strike posture does not influence impact peak magnitude (P=0.1). The impact peaks produced by chimpanzees during bipedal walking (0.61±0.11 BW [body weights]) were similar to those previously reported for humans (0.69±0.1 BW; Lafortune and Hennig, 1992). However, chimpanzees incurred much lower impact peaks when walking quadrupedally (0.37±0.17 BW), and produced no impact peak in 23% of the quadrupedal steps we measured. These results suggest that in adopting habitual bipedalism, early hominins would have had to adjust to high impact forces. Although modern humans are capable of avoiding impact peaks during running by switching from heel to forefoot striking, our results suggest that adjusting foot strike posture may not have helped early hominins reduce impact forces during walking. Therefore, hominins may have needed to evolve anatomical specializations to withstand the shock associated with foot strike. Supported by NSF 0935321.

4.6 HOLT, N/C*; EATON, C/E; AZIZI, E; Univ. of California, Irvine; *eazizi@uci.edu*

Structural limits to mechanical work production in skeletal muscle

Skeletal muscles generate the mechanical work needed to accelerate or raise an animal's center of mass during locomotion. Therefore, a muscle's capacity to generate mechanical work can be an important determinant of locomotor performance. The work generated by muscle is the product of active force produced by contractile tissues and the shortening undergone. During shortening, the muscle must bulge outwards to remain isovolumetric. This bulging may be restricted by the network of connective tissues that surrounds muscles. Hence, connective tissue constraints to shortening may impact a muscle's ability to generate work. We modeled the interaction between muscle and connective tissue using a pressurized, fiber-wound cylinder to define the conditions where connective tissues may limit muscle work. This model was combined with two sets of experiments. In the first we compared the shortening and mechanical work capacity of a muscle with and without the presence of a physical constraint that restricted radial expansion. In the second we compared the shortening and mechanical work capacity of fiber bundles from a fibrotic (old) muscle before and after the application of a collagenase treatment. In these experiments, the collagenase decreased the connective tissue structure within the muscle and likely released the physical constraints to radial expansion. Taken together, our results show that shortening and mechanical work are constrained when the radial expansion of a muscle is restricted and that removing such constraints can recover the capacity to generate work. This work elucidates how the fundamental interactions between contractile and connective tissue structures affect contractile performance.

24.7 HOLZMAN, R*; AVIDAN, L; Tel Aviv University; *holzman@post.tau.ac.il*

Effect of flow speed on aquatic predator-prey interactions

Flow is a major factor for life in water, affecting multiple fitness-determining functions such as reproduction, mass transfer, and the rate of encounter with prey and predator. While many fish species depend on the flow of water to carry the prey towards them, little is known on the mechanistic effect of water flow on the interaction between the prey and the predator. In this study, we used a recirculating flume to expose a station-keeping fish predator, *Chromis viridis*, to increasing approach speeds of their prey, Mysid shrimps. We tested the hypothesis that faster flows will reduce the response time of the prey, leading to increased capture success with increasing flow speed. Our results supported the hypothesis, with a doubling in the frequency of unsuccessful prey escape responses at fast flows (0.25 m/s) compared to slower speeds (<0.1 m/s). The increasing failure frequency was attributed to a delayed initiation of the prey's escape response in high flow speeds. Lastly, we tested whether the prey responds to the predator's kinematics by correlating the PC scores of predators' strikes and those of prey escape. However, there was no significant correlation between the two factors. Our results show that water flow can have a strong mechanistic effect on predator-prey interactions.

135.3 HOOD, WR*; ZHANG, Y; Auburn University, Auburn University ; *wrhood@auburn.edu*

Understanding the bioenergetic mechanisms that underlie the interactions among life history traits

Historically, investigators have evaluated the cost of reproduction and its predicted impact on future reproduction and survival by evaluating metabolic rate. More recently, studies have quantified oxidative damage as a likely mediator of life-history trade-offs. Despite these efforts, researchers have failed to satisfactorily describe the mechanisms responsible for interactions between survival and reproduction. We believe that there are at least two important reasons for the equivocal nature of proposed explanations: 1) investigators typically assume a negative, linear relationship between current reproduction and future reproduction and survival, even when empirical studies do not consistently show patterns that are negative or linear, and 2) studies often fail to target mechanisms that could link interactions between sequential life history events. We will review published work and present new data on how mitochondrial function changes in response to reproduction and aging in female house mice. The importance of considering differences in the metabolic function among organs and the timing of sample collection will be discussed. Finally, it will be argued that the costs of reproduction can be ephemeral, persistent, or delayed. As a result, it is critical that investigators carefully consider additional measures of bioenergetic function in their studies, including measures of oxidative repair, mitochondrial biogenesis, cell proliferation, mtDNA mutation and replication error, and importantly, a measure of the respiratory function of mitochondria (RCR, P/O) to determine if measured differences among individuals are associated with a change in the energetic capacity of tissues. With this new perspective, we should gain greater insight into the mechanisms responsible for variation in the pace of life displayed among individuals.

P1.47 HOOD, KE*; RAMIS, F; HURLEY, LM; Indiana Univ., Stetson Univ.; *hoodk@indiana.edu*

Male Mice Respond to Dismissive Female Repertoires

House mice (Mus musculus) are a growing model for the study of context-dependent vocal communication. During courtship interactions, successful mating attempts are associated with a high level of production of ultrasonic vocalizations (USVs) by males, and an increased proportion of specific classes of USVs. USVs have been well- studied, but there is very little information on the role of female broadband vocalizations (BBVs). BBVs are produced with female rejection behaviors, and are associated with decreases in the likelihood of male mounting. We examined the potential role of BBVs in courtship interactions by measuring the vocal and nonvocal behaviors of male mice exposed to a novel female with or without a BBV playback. We also compared the response of male mice to female calls between two strains (CBA/J and Balb/C) with different levels of sociality. In order to measure these responses without the impact of female rejection behaviors, males and females were placed on opposite sides of a plexiglass barrier with a single contact point that was large enough for olfactory investigation but not large enough for direct contact. In interactions with a barrier, males produced the same number of USVs as in natural interactions, including USV types associated with mounting attempts or close investigation. Both strains decreased their overall USV production when presented with BBV playback but only male CBA/J mice also decreased the number of mounting-associated USVs produced. No significant difference in duration of non-vocal male behaviors including, time at the contact point, digging, and self-grooming, was found between interactions with or without playbacks. These results suggest that BBVs alone modify male behavior and that this behavioral modification is related to the sociality of the strain.

9.2 HOOVER, KM*; BUBAK, AN; LAW, IJ; YAEGER, JDW; RENNER, KJ; SWALLOW, JG; GREENE, MJ; University of Colorado Denver, University of Colorado Anschutz Medical Campus, University of South Dakota; *kevin.hoover@ucdenver.edu*

The organization of societal conflicts by pavement ants Tetramorium caespitum: an agent-based model of amine-mediated decision making.

Ant colonies self-organize to solve complex problems despite the simplicity of an individual ant' s brain. Pavement ant colonies must solve the problem of defending the territory that they patrol in search of energetically rich forage. When members of two colonies randomly interact at the territory boundary a decision to fight occurs when 1) there is a mismatch in nestmate recognition cues and 2) each ant as a recent history of high interaction rates with nestmate ants. In ants, the monoamines serotonin and octopamine modulate behaviors associated with nestmate recognition and aggression. We develop and explore an agent based model that conceptualizes how individual changes in brain concentrations of monoamines, paired with a simple threshold based decision rule can lead to the development of colony wide warfare. Model simulations do lead to the development of warfare with 91% of ants fighting at the end of 1 hour. When conducting a sensitivity analysis we determined that uncertainty in monoamine concentration signal decay influences the behavior of the model more than uncertainty in the decision making rule or density. We conclude with the conceptualization of a "monoamine clock" mechanism that would explain the behavior observed in the model.

67.4 HOPE, SF*; DURANT, SE; HALLAGAN, JJ; BECK, ML; KENNAMER, RA; HOPKINS, WA; Virginia Tech, Oklahoma State University, University of Georgia; *shope@vt.edu*

The Effect of Clutch Size on Incubation Behavior and Within-Nest Egg Temperature Variation

To maximize lifetime reproductive success, animals must optimize allocation of time and energy to parental care and self-maintenance. In birds, incubation is crucial to maintain egg temperatures. Even small differences in mean temperature affect phenotypes critical to offspring survival, but incubation may diminish a parent's time or energy available for self-maintenance. Large clutches are costly to warm, and may be a challenge for maintaining temperatures. Understanding parental behavior when faced with large clutch sizes, and how it affects egg temperatures, can provide insight into how parents cope with the parental care/self-maintenance tradeoff, and the effects on their offspring. To investigate this, we studied Wood Ducks, which are uniparental incubators with an average clutch size of 12 eggs, but nests reach >30 eggs due to conspecific brood parasitism. We manipulated clutch size in a box-nesting population and recorded hen incubation behavior along with temperatures of 7 artificial eggs within each nest during incubation. We found that as clutch size increased, hens took fewer, longer off-bouts, suggesting that hens can detect clutch size or associated temperatures and modulate their behavior. Clutch size was correlated negatively with mean nest temperature and positively with variation in mean temperature among eggs within a nest. Yet, hen mass loss during incubation did not differ. This suggests that hens shift investment towards self-maintenance (body mass) over parental care (egg temperature). Further, maintenance of optimal egg temperatures, which in turn affect offspring phenotype, may constrain the evolution of larger natural clutch sizes and be an overlooked cost of brood parasitism.

S7.6 HOPKINS, Melanie J.; American Museum of Natural History; *mhopkins@amnh.org*

Trait development and evolution in trilobites

Trilobites offer the best fossil record of any arthropod. This is due to a number of factors, most notably the combination of 1) having inhabited areas where organisms are more likely to be buried and ultimately fossilized; and 2) having had a highly biomineralized exoskeleton more likely to survive the stresses of fossilization. This biomineralized exoskeleton was also morphologically complex, bearing traits that had ecological significance, and was present throughout postembryonic development, from larval to adult stages. Because the morphology of the exoskeleton changed gradually across molts during development, it is possible to reconstruct ontogenetic series for many species. Over the last decade, studies have documented both variation in modularity among closely related species and conserved developmental patterns among modules. In the latter case, trait evolution can still occur through modification of rates of morphological change along otherwise conserved ontogenetic trajectories. At the clade level, the pattern of expression and release of new exoskeletal segments during post-embryonic development was generally conserved across most species, but the relative timing of different segmentation events could vary, and per-molt growth rates appear to have been relatively labile across the clade's evolutionary history. Most recently, comparative analyses indicate that the association between segmentation events and the timing of shifts in the rate of ontogenetic shape change varies across species. Despite these advances, we still know relatively little about how development constrains or contributes to trait evolution in trilobites, and almost nothing about the origin of novel traits in trilobites. A major (but removable) obstacle is the current lack of well-supported trilobite phylogenies that span higher taxonomic levels.

P3.75 HOPP, B*; ARVIDSON, R; ADAMS, M; RAZAK, K; Univ. of California, Riverside; *bhopp002@ucr.edu*

Arizona bark scorpion venom resistance in the pallid bat, Antrozous pallidus

The pallid bat (*Antrozous pallidus*) is a gleaning bat found in the western United States and Mexico. It hunts a wide variety of ground-dwelling prey, including scorpions. Anecdotal evidence indicates that the pallid bat is resistant to scorpion venom, but no systematic study has been performed. Here we show with behavioral measures and direct injection of venom that the pallid bat is resistant to the venom of the deadly Arizona bark scorpion, *Centruroides sculpturatus*. Our results show that the pallid bat is stung multiple times during a hunt, and the venom has no effect on its behavior. We also tested pallid bats from three regions in the southwest USA to test whether venom resistance varied with sympatry or allopatry to *C. sculpturatus* and found no difference in venom resistance. Scorpion venom is a cocktail of molecules, some of which hyper activate voltage-gated sodium ion channels and cause intense pain. Dorsal root ganglia (DRG) contain nociceptive neurons and are principal targets of scorpion venom. To understand if mutations in specific ion channels underlie venom resistance, the transcriptome of the pallid bat DRG was generated. As sodium channels are the principal targets of scorpion venom, we identified amino acid substitutions present in the pallid bat DRG which may grant venom resistance. These substitutions are similar to corresponding amino acids in sodium channel isoforms responsible for reduced venom binding activity. The substitution found previously in grasshopper mice rendering venom resistance is not present in the pallid bat, showing that the pallid bat has acquired venom resistance using a different mechanism. Future studies will test the amino acid substitutions identified in the pallid bat DRG using patch clamping and cell lines to understand mechanisms of venom resistance.

19.1 HOUSTON, D. D.; AZEEM, S.; LUNDY, C.; SATO, Y.; GUO, B.; BLANCHONG, J. A.; GAUGER, P. C.; YOON, K. J.; ADELMAN, J. S.*; Iowa State University; *adelmanj@iastate.edu*

No evidence of a role for wild songbirds or rodents in spreading avian influenza virus across an agricultural landscape

The 2015 outbreak of highly pathogenic avian influenza virus (AIV) among domestic poultry in the Midwest was the worst in US history. Because the strain of AIV responsible had been previously found in wild ducks, and because waterfowl are known to be reservoirs of AIV in general, these species were widely reported as a likely cause of the outbreak. Waterfowl, however, are rarely found in or near commercial poultry barns, raising the question of how AIV would move from its natural reservoir into poultry. One possibility is that small terrestrial birds or mammals served as vectors, moving the virus from wetland to farm. To assess the likelihood of this scenario, we sampled over 400 individuals from 39 species of small birds and mammals at sites across Iowa during the fall of 2015 and spring of 2016, after the AIV epidemic had subsided in poultry. We swabbed both internally (mouth and cloaca/anus) and externally (feet and feathers/fur) to test for the virus via qPCR. In addition, we drew blood to test for prior exposure via antibodies against AIV. We found no evidence of current or prior exposure to AIV in small birds and mammals, estimating a 95% confidence interval of true prevalence to be 0.00-0.74%. During our surveillance, governmental organizations did detect AIV in waterfowl across Iowa, at an observed prevalence of up to 15%. So, even though AIV was present on the landscape, small birds and mammals were unlikely to play a major role in moving the virus from wild to domestic species.

31.2 HOWEY, CAFH*; ROOSENBURG, WM; The Pennsylvania State University, Ohio University; *cah62@psu.edu*

Effect of Temperature on Snake Locomotion and the Interpretation of Thermal Performance Curves

Environmental temperatures dictate ectotherm body temperatures (T_b) which has consequences regarding behavioral and physiological processes. Crawling speed is very important to the black racer (*Coluber constrictor*), given that it uses this behavior to chase down prey and outrun potential predators. To measure the effect of temperature on *C. constrictor* crawling speed, we conducted thermal performance trials on 17 individuals. We manipulated snake T_bs to specific test temperatures (10, 20, 30, 35, 37.5 °C) and then raced each individual down a straight track. We video recorded each trial and measured the forward velocity of each snake using Tracker Video Analysis software. Snakes performed better at 35 °C then they did at lower T_bs. We determined the thermal performance breadth (B_{80}) to be between 29.1 - 37.7 °C. However, during performance trials, we observed differences with regard to snake kinematics. We further analyzed each trial video using the Tracker Video Analysis software to determine the kinematic properties of each snake at each test temperature. These kinematic properties were then compared to the set properties of each mode of snake locomotion as described by Jayne (1985). When T_bs were within the B_{80} range, snakes were able to use lateral undulation. However, at low T_bs snakes were constrained to using concertina locomotion and at 20 °C snakes appeared to be transitioning between the two types of locomotion. Thus, our thermal performance curve for "locomotion" was actually comparing two very different modes of locomotion, and not necessarily the same behavior. Future research on snake thermal performance curves should account for thermal effects on kinematics and mode of locomotion.

98.8 HSIEH, ST*; SHAMBLE, P; WILSHIN, S; HOVEY, K; SPENCE, AJ; Temple University, Harvard University, Royal Veterinary College; *sthsieh@temple.edu*

Spiders "limp" to achieve a more stable gait

Many invertebrates are capable of voluntarily losing limbs (autotomy) in response to antagonistic encounters. How they rapidly adapt to such an extreme perturbation of the locomotor system is poorly understood, however. Wolf spiders are fast-running, active predators that are frequently found in nature missing one or more limbs. We used wolf spiders to address the question: if an eight-legged spider loses two limbs, will it run like an intact six-legged animal or like an eight-legged animal that has lost two limbs? After running intact spiders 30 times to obtain baseline control data, we autotomized two limbs specifically selected to induce a maximally unstable condition during one half of the stride cycle, and then ran them 30 more times in the ablated condition. We hypothesized that in response to such a destabilization, spiders would adopt a more stable, novel limb pairing ("modified tripod gait"), potentially at the cost of decreased running speeds. Our results showed that limb ablation did not cause a measurable decrease in running speeds. When intact, spiders ran with an alternating tetrapod gait. Following limb ablation, spiders tended to switch their limb pairings to the more statically-stable 3-3 limb pairing modified tripod gait, but also often continued running without changing gaits ("ablated tetrapod gait"), stepping with a four-limb tetrapod followed by an unstable two-limb vault. Surprisingly, our stability calculations showed that there was no difference in stability between the modified tripod and the ablated tetrapod gait. A temporal analysis revealed that spiders were able to achieve a more stable ablated tetrapod gait by decreasing the time spent in the two-limb vault, thereby "limping" to increase the average stability of a stride.

71.5 HU, Y.*; MAJORIS, J.E.; BUSTON, P.M.; WEBB, J.F.; University of Rhode Island, Boston University; *yinan_hu@uri.edu*

Development of the nose and internal taste buds in two species of neon gobies (Elacatinus spp), and their potential to facilitate navigation of pelagic larvae.

The discovery that pelagic fish larvae are not just passive particles, but have the ability to demonstrate directional behaviors in the open ocean and locate appropriate settlement sites has intrigued biologists for many years. Yet it is still unclear which sensory modalities foster this capability. Morphological analysis of the ontogeny of the various sensory organs can shed light on their functional capacities. In this study, we reared two neon goby species native to Belizean reefs (*Elacatinus lori* and *Elacatinus colini*) in a field laboratory and describe the developmental morphology of the olfactory organ and internal taste buds from day-of-hatch through settlement (~30 days post hatch). Histology and SEM show that both sensory systems develop in a manner consistent with that of other reef fishes, with notable changes around the time of settlement. The olfactory epithelium is present at hatching, and later invaginates and becomes enclosed in a blind sac with two nares at settlement stage. There is no sign of lamellae or accessory nasal sacs, which would otherwise indicate the capacity for active nasal ventilation. Internal taste buds are abundant in the buccal cavity, with the majority on the gill arches (including pharyngeal jaws) and the roof of mouth. The distribution of taste buds shows a "spread" to more rostral positions within the buccal cavity (lips, buccal valves and "tongue") as the larvae approach settlement. The implications of these ontogenetic trends for larval navigation will be discussed. Funded by NSF grant 1459224 to JFW and 1459546 to PMB.

84.6 HUBBARD, AM*; SCHIEBEL, PE; RIESER, JM; GOLDMAN, DI; Georgia Institute of Technology; *alexmhubbard.1994@gmail.com*

Force Production during Desert Specialist Snake Locomotion

The Mojave Shovel-nosed Snake (*C. occipitalis*) is a small (~40 cm, ~18 g) desert-dwelling sand specialist which travels on the surface of sand with low slip and high speed using a stereotyped undulatory gait—a traveling wave of sinusoidal body curvature with fixed amplitude and number of waves. These animals also encounter obstacles such as plants and rocks. To test how this behaviorally rigid animal contends with such heterogeneities and if it is helped or hindered by them, we study in the laboratory the locomotion of the snakes (N=8) through a model of twig-like obstacles—a single row of six 0.64 cm diameter stiff rubber pegs 2.3 cm apart oriented perpendicular to the animals' direction of motion. To enable effective locomotion, we embedded the pegs in a carpet substrate which mimics deformable sand but without complications such as substrate hysteresis. Despite inability to see (the spectacles were painted with non-toxic acrylic), the animals rapidly transited through the pegs (the speed exiting the pegs was ~0.62 to 1.1 times the initial speed). To understand how performance was maintained, we measured the angular distribution of the reaction forces via video observation of small peg deflections. Forces were rarely applied along the direction of motion (forward or backward). This suggests that, unlike generalist snakes, the specialist *C. occipitalis* does not modify its waveform to use the obstacles, instead relying on substrate deformation. In contrast, force was generated perpendicular to the motion. To determine the origin of this force pattern, we studied the dynamics of a robotic snake transiting an array of posts. We observed a similar force pattern in the robot further supporting the notion that the snake does not drastically modify its neuromechanical control during obstacle interaction.

63.7 HUBICKI, CM*; AGUILAR, JJ; KIM, AH; AMES, AD; GOLDMAN, DI; Georgia Institute of Technology; *christian.hubicki@me.gatech.edu*
Manipulation of grain-scale mechanics improves robot jumping performance
Substrate dynamics can have a significant impact on terrestrial locomotion behaviors; for example, movement strategies that perform well on hard ground can lead to failure on yielding substrates like granular media. We performed a robophysical experiment to investigate how granular media dynamics can be manipulated to modify performance in a simple behavior, jumping. Using recent models of granular bulk reaction forces during rapid intrusions [Aguilar & Goldman, Nature Physics, 2015] and a numerical optimal control algorithm, we control a jumping robot to leap from a bed of loose packed poppy seeds to a commanded apex using minimal motor work. The optimal controller was able to exploit the terrain dynamics to jump to commanded heights; the patterns of robot self-deformation differed from those which produced similar heights on hard ground. For a subset of optimized behaviors, jumps overshot the commanded/predicted apex height by ~40%. In particular, this excessive jump height occurred when the intruding foot briefly (~40 ms) halted its penetration before resuming its downward thrust. As a result, we hypothesized the presence of additional un-modeled terrain dynamics which activate when the intruder pauses. In testing this hypothesis, intrusion force measurements confirmed the production of anomalous resistive force after a paused penetration. Back-scattered laser speckle measurements revealed that, after a paused intrusion, grain motion decayed on a similar timescale (10 to 100 ms) to the required pause time of the anomalous jumps. The findings of this mutualistic interaction between soft matter physics and optimal robotic control underscores how seemingly subtle substrate physics may potentially incentivize exotic locomotion behaviors in robots and organisms alike.

P1.51 HUDSON, SB*; SMITH, GD; DURSO, AM; FRENCH, SS; Utah State University; *spencerbrucehudson@gmail.com*
Reproductive Coloration and Physiology in Female Side-blotched Lizards (Uta stansburiana)
Female-specific reproductive coloration is extensive across lizard species, prompting exploration into the potential functions and costs of such traits. Females entering vitellogenesis may produce coloration for signaling aspects of fertility and self-maintenance while affording the costs of reproduction. Exhibiting conspicuous signals could incite male-male competition and perhaps lead to greater sperm competition. Changes in color signals may alternatively deter male attention when females are gravid with eggs or embryos, and thus reduce female costs of reproduction. Using free-living female common side-blotched lizards (*Uta stansburiana*) as a study species, we compared aspects of innate immunity and oxidative stress across vitellogenic stages to determine potential cost differences throughout reproduction. We also compared orange-throat coloration across vitellogenic stages to determine any differences in signaling for reproductive state. Within vitellogenic stages, we investigated relationships between orange-throat coloration and physiological metrics including innate immunity, oxidative stress, and follicle development. At the onset of vitellogenesis, females have significantly greater oxidative stress than those in late-gravid stages. During gravidity, females exhibit significantly greater antioxidant capacity and a significant decrease in innate immunity. Orange-throat coloration is not correlated with any physiological metrics across vitellogenic stages, but is instead positively correlated with follicle development and innate immunity in females at the height of reproductive investment. These data suggest that female *U. stansburiana* honestly signal fertility and self-maintenance when they are affording the costs of mid-vitellogenic investment. Further, this reproductive time-point may be a critical period during vitellogenesis for females to attract males for fertilization.

40.1 HUDSON, DM*; CARDONA, LF; CORTES MUNAR, JS; PHILLIPS, G; SMITH, Q; ROCHA, MH; Atlanta Metropolitan State College, Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Georgia State University; *dhudson@atlm.edu*
Spatial Competition Between the Native Colombian Freshwater Crab, Neostrengeria macropa, and the Invasive Red-Clawed Crayfish, Procambarus clarkii.
The endemic Colombian freshwater crab, *Neostrengeria macropa*, has recently encountered an invasive species in *Procambarus clarkii*, the Louisiana red-clawed crayfish. This invasive crayfish species has been identified across the United States, Central and South America, Europe and Asia. In our experiments, *P. clarkii* competes with *N. macropa* for shelter and food that can be important aspects of coexistence in the Andean streams in which *N. macropa* is endemic. To predict which species will survive, a series of behavior experiments were performed in laboratory mesocosms to determine the role of direct competition for shelter. This included individual competition for space and shelter usage, competition within species for shelter usage, as well as interactions between the two species. Preliminary data analysis shows that *P. clarkii* outcompetes *N. macropa* for shelter space, but *N. macropa* will also utilize land adjacent to water. Extrapolating the consequences of this invasion is difficult, but the use of land by the pseudothelphusid crab may allow it to coexist in these streams. However, other confounding factors in the invasion may include the potential for pathogens to pass from the invader to this endemic population, which has happened on other continents.

P2.20 HUDSON, DM; THOMPSON, JF; PHILLIPS, G*; ROCHA, MH; Atlanta Metropolitan State College, Universidad Nacional de Colombia Instituto de Ciencias Naturales sede Bogota; *gillianlynphillips@gmail.com*
Behavioral effects of salinity changes to the Colombian freshwater crab, Neostrengeria macropa
Neostrengeria macropa is a freshwater crab native to the Bogotá plain of Colombia South America. This brachyuran crab is consumed as a food item and is found in markets across Bogotá and could become an at-risk species due to indiscriminate fishing. Large industry such as salt and oil mining have the potential to affect salinity of freshwater systems in their native range. Behavior experiments with a two-chambered tank with one side freshwater and the opposite side with an increasing salinity from 0 psu to 15 psu. Preliminary data shows that as salinity increases the amount of time spent burrowing decreases while the amount of time out of water increases. Increasing salinity in freshwater systems could be linked to both natural and industrial causes. Industry impact will be mapped based on locations and type of industry and compared with the native range of *N. macropa* in Colombia. Management of industrial effects on ecological systems may need to be implemented to reduce effects of salinization of ground water and river systems due to anthropogenic factors.

P1.67 HUDSON, D.M; SMITH, Q.M.*; PHILLIPS, G.L; HORTON, I; Atlanta Metropolitan State College; *quandasmith08@gmail.com*

Invasive and Native Crayfish Growth and Survival on Two Feed Types

The large diversity of crayfish in the Southeastern United States has resulted in a need to quantify not only the geography of each species, but also how those species at risk may be cultivated in a hatchery environment to augment populations. We have collected crayfish in northern Georgia and are seeking to develop a protocol to cultivate these in the lab in conjunction with the U.S. Fish and Wildlife Service. Additionally, we tested the viability of a new feed derived from dehydrated food waste from restaurants in the development of these detritivores. With up to 40% loss of food to waste each year in the United States, any use of food waste for purposes other than mulch can help take pressure off landfills and can reduce the concentration of nutrients in waterways. As such, we tested this feed on the Louisiana red-clawed crayfish, *Procambarus clarkii* , along with a control commercial shrimp pellet. We raised crayfish from hatching over several months to observe mortality rate, growth rate, and coloration. Thus far, there is no significant difference between the feeds in their mortality rate or growth, as the experiment started off with 180 *P. clarkii* larvae, and ran over the course of 10 weeks. We are reporting not only these data, but growth and mortality data on native Georgia crayfish to the same conditions. Through enhancing their diet with this feed, we expect to have similar growth rates and carapace hardness and color in the long term, and can therefore influence the supply chain of aquaculture operators to use a more sustainable source of nutrition for their animals.

P1.1 HUFFMYER, AS*; LEMUS, J; Hawaii Institute of Marine Biology, University of Hawaii at Manoa; *ashuff@hawaii.edu*

TEACHING STYLE IMPACTS STUDENT ACHIEVEMENT IN A RESEARCH-BASED UNDERGRADUATE SCIENCE COURSE

Inquiry-based instruction in undergraduate science courses connects students to research and prepares them for careers in science, technology, engineering, and mathematics (STEM). Often, graduate Teaching Assistants (TA) with differing experience and teaching methods are responsible for leading hands-on laboratories. This study determined how differences in TA teaching methods and styles impact student achievement in an ecology research course at the University of Hawaii, Manoa. In this course, TAs write their own weekly quizzes and teach material according to their personal teaching style. We observed TA teaching style by measuring the use of open and closed questioning, pacing, use of instructional media, question wait time, and other indicators that have been shown to affect student learning. We measured differences in student responses on concept surveys and analyzed quizzes with Bloom's Taxonomy. Several characteristics of teaching style, including instructional methods and type of questioning, were significant predictors of student scores in homework, quiz, and research project areas. The time spent discussing homework in class was a particularly strong driver in patterns of student achievement and scores. In addition, students received the lowest quiz scores and had no improvement in homework scores when asked to define or recall concepts on weekly quizzes while students received higher quiz and homework scores when asked to analyze and synthesize concepts. These results indicate that TA teaching methods may have a stronger impact on student achievement than previously known. This research suggests universities should provide training for TAs to develop teaching methods that promote student achievement in inquiry-based undergraduate courses in STEM disciplines.

P2.160 HUGHES, R*; CUNNINGHAM, GB; St John Fisher College; *ryanhu@auamed.net*

Embryonic exposure to scents by chickens (Gallus gallus domesticus) leads to heightened sensitivities

Many studies have demonstrated that when newly hatched chicken (*Gallus gallus domesticus*) chicks are exposed to odors, they later show preferences for food or locations that are appropriately scented. Scents, however, also readily cross the eggshell, and thus it has been demonstrated that exposure to a scent in ovo also causes altered food consumption in exposed chicks after hatch. And yet, we do not know if this embryological exposure causes the chicks to be more sensitive to the scent. Here we exposed a group of chicken eggs to an orange scent in the days prior to hatch and tested these, and unexposed, one day old chicks to a dilution series of orange scents. We found that orange-exposed chicks responded to the orange scent at lower concentrations than the unexposed chicks. This suggests that embryonic exposure to an odor either alters the makeup of the olfactory epithelium or the conditions of the olfactory bulb or both. This increased sensitivity towards smells experienced in the egg may allow precocious chicks to more easily find food. We also found that orange-exposed chicks responded more strongly to another fruity scent (raspberry) than non-exposed chicks. These results are also discussed.

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Thermoregulatory patterns of non-native Anolis sagrei in a novel thermal environment

The northward spread of non-native reptiles is often limited by low minimum temperatures as latitude increases. Man-made structures, however, create novel thermal environments that maintain higher temperatures than surrounding natural areas. These structures may provide a suitable habitat for non-native reptiles, allowing them to extend their range. A population of Cuban brown anoles, *Anolis sagrei*, have been occupying a series of greenhouses in Auburn, Alabama, since at least 2006. The greenhouses are farther north than most other main populations of brown anoles in Florida, but temperatures can exceed 45°C on the inside during the summer months (a temperature near or above the critical thermal maximum for many reptiles). We set out to collect data on the thermoregulatory behavior of these lizards both inside and outside the greenhouses during summer months. We placed iButton data loggers on varying substrates to collect temperatures. We also conducted visual surveys by walking transects and recording lizard sightings inside and around the greenhouses. Preliminary results suggest that anole behavior is uncharacteristically crepuscular; they are more active inside the greenhouses during the cooler morning and evening hours. Instead of traveling outside during mid-day when temperatures are the warmest, they appear to be utilizing a variety of substrates to thermoregulate. During the winter months, similar data will be collected to discover how this population survives as outside temperatures drop much lower than they would experience in the lower latitudes of their non-native range.

P1.34 HULSE, SV*; MENDELSON, TC; University of Maryland Baltimore County; *hsamuel1@umbc.edu*

Efficient Coding and the Emergence of Sensory Biases

Sensory bias plays a pivotal role our modern theory of sexual selection. Despite this, mechanisms for how biases emerge are only partially understood. The efficient coding hypothesis posits that organisms' sensory systems evolve to represent environmental stimuli in a way which is the least metabolically or developmentally costly. One way this can be accomplished is by removing statistical redundancies from sensory inputs to minimize the number of spikes required to represent a stimulus. In the context of visual perception, the visual cortex is thought to perform these computations. Since visual statistics vary by habitat type, the efficient coding hypothesis would predict that species will evolve to most efficiently encode their species-specific visual habitat. This is potential route for the evolution of a sensory bias; many studies in humans and non-humans have shown preferences for efficiently coded stimuli. If males can mimic the visual statistics of their environment, it could increase their attractiveness to females. We aim to test this prediction, using darters (genus Etheostoma) as a model system. We collected males representing four species with distinct habitat preferences, and captured photographs of males themselves and their native habitats. By training a sparse autoencoder on each habitat type, we can roughly mimic how the visual cortex processes information. By inputing images of males into networks trained on their habitat type, we can see whether the network has a lower activation level for males from that habitat versus males from other habitats. The lower activation level of the network is analogous to the minimization in spikes predicted by the efficient coding hypothesis. This would also represent compelling evidence that male displays have evolved to match the visual statistics of their environments through sexual selection.

62.1 HUMFELD, SC*; GRUNERT, B; University of Missouri, Michigan Technological University; *humfelds@missouri.edu*

Climate Change Unlikely to Impact Sexual Communication in a Widely-Distributed Treefrog.

Males of many animal species produce conspicuous signals to attract mates; male treefrogs produce loud and persistent acoustic signals called advertisement calls. Frogs face an interesting challenge: temperature can differentially impact signal production and perception, leading to a mismatch between sender and receiver. For instance, female Green Treefrogs (*Hyla cinerea*) exhibit temperature-sensitive preferences for the frequency of the advertisement call, potentially resulting in interspecific hybridization at low temperatures. Considering climate predictions by the Intergovernmental Panel on Climate Change, we investigated whether, and by how much, temperature modifies female preferences for natural variation in spectral properties of male advertisement calls. Females of the Gray Treefrog (*H. versicolor*) prefer calls with standard bimodal frequency peaks of 1100 and 2200 Hz over calls with higher and lower frequencies. These preferences were determined at 20° C, but the dominant frequency of calls is positively correlated with temperature. Using two-speaker choice experiments, we tested the hypothesis that acoustic preferences of female *H. versicolor* vary based on ambient temperatures (15, 20 and 25° C). We found that female preferences based upon frequency are, at best, only moderately temperature dependent. We discuss the properties of the two inner-ear organs and possible neurophysiological explanations for the seeming lack of temperature coupling in this aspect of the Gray Treefrog communication system. We conclude that mate-choice decisions based on frequency will not be significantly impacted by modest (2° C) changes in predicted environmental temperatures.

S4.6 HUMPHRIES, Murray M*; MENZIES, Allyson K; STUDD, Emily K; McGill University; *murray.humphries@mcgill.ca*

The seasons of things and the purposes of time: seasonal variation in morphology, metabolism, and behaviour in boreal endotherms

The pervasiveness of seasonality, including seasonal variation in the targets of time allocation, are well recognized. But the extent to which an all-season genotype can express a phenotype suitable for every season remains poorly examined. The metabolic design of organisms varies along a continuum from slow and flexible (i.e., low metabolic requirements that can be further lowered during periods of resource scarcity) to fast and invariant (i.e., high metabolic requirements independent of resource availability). Homeothermic endotherms are situated at the fast and invariant endpoint of this continuum, yet are common year-round residents in the world's most seasonal environments. We quantify the forms of morphological, physiological, and behavioural plasticity expressed by free-ranging homeothermic endotherms in the boreal forests of northern Canada. In particular, we assess the plasticity of body size, body composition, organ size, insulative capacity, resting and field metabolic rates, diet, habitat use, and activity patterns. In addition, we present a conceptual and analytical framework that assesses the relative contributions of variation in each of these traits to overall seasonal plasticity. In general, traits most directly related to behaviour (e.g., diet, habitat use, activity, field metabolic rate) vary the most and therefore matter the most to the seasonal plasticity of homeothermic endotherms. These results reveal how seasonality can be either muted or amplified in the interaction strengths that structure boreal food webs and offer insights into the plasticity and evolutionary design of endotherms occupying highly seasonal environments.

55.1 HUNT, KE*; LYSIAK, NS; MOORE, MJ; SETON, RE; ROBBINS, J; N Arizona Univ, New England Aquarium, Woods Hole Oceanographic Institution, College of the Atlantic, Center for Coastal Studies; *Kathleen.Hunt@nau.edu*

Multiple Steroid and Thyroid Hormones Detected in Baleen from Seven Whale Species

Recent studies have demonstrated that progesterone and cortisol are detectable in baleen from two closely related species of mysticete whale, North Atlantic right whale (*Eubalaena glacialis*, NARW), and bowhead whale (*Balaena mysticetus*). Longitudinal profiles of both hormones in baleen appear to match known reproductive history across the period of baleen growth. We wished to determine whether other hormones are also detectable in baleen, and whether baleen hormones are detectable in other species. Powdered baleen samples were recovered from single baleen plates from stranded specimens of NARW, bowhead, sei (*Balaenoptera [B.] borealis*), fin (*B. physalus*), blue (*B. musculus*), minke (*B. acutorostrata*), and humpback (*Megaptera novaeangliae*) whales. For all species we tested hormone detectability, parallelism and (where sample volume permitted) accuracy, using commercial enzyme immunoassays for progesterone, cortisol, corticosterone, 17β-estradiol, testosterone, aldosterone, thyroxine and tri-iodothyronine. All hormones were detectable in baleen powder of all species and validation results were consistently good. Though data are limited to single samples from each species, these findings indicate that baleen hormone analyses may be applicable to a broad range of mysticetes. The variety of hormones detected suggests that baleen hormone analysis might be a suitable technique with which to explore questions that are often difficult to address in large whales, potentially including: pregnancy and inter-calving interval, estrous cycling in females, testosterone cycles in males, sexual maturation in both sexes, seasonal reproductive cycles, adrenal physiology, and metabolic rate.

84.5 HUNT, NH*; FRENDBERG-MATES, E; JINN, J; ROBIN, A; JACOBS, LF; FULL, RJ; Univ. of California, Berkeley; *nathaniel.hunt@berkeley.edu*

Squirrels Running on Compliant Branches: When to Leap?

Many arboreal animals traveling through the canopy are challenged to stably walk or run, and then to leap from compliant branches to cross gaps and land on a target. As animals traverse further from the trunk, compliance increases while the gap size to be crossed decreases. We've previously shown that both greater compliance and larger gaps increase the difficulty of targeted leaping. Therefore, a tradeoff is presented between the length of the gap that must be crossed and the compliance of the substrate at any chosen takeoff point. We created an outdoor arena with interchangeable compliant rods and a small landing perch. We trained free-ranging fox squirrels (*Sciurus niger*) to run and leap across a gap using rods of equal diameter but with low, medium or high compliance. Rods were cantilevered 90 cm across a 100 cm gap. Beam compliance increased to the third power along the length of the rod. Vertical displacements at the 50% along the rod due to body weight were 1.6, 5.0 and 23.9 cm for the low, medium and high compliance rods, respectively. Squirrel traversal behavior was affected by rod compliance. On the least compliant rod, they leaped from a full range of points or walked onto the landing perch. On greater compliance rods, they elected to leap earlier - across longer gaps. When walking or running across the rod, squirrels splayed their toes prior to each footfall, leaped with one hind limb in front of the other, creating asymmetry during launch, and then brought their feet in alignment with the landing perch for contact using contralateral symmetry, first fore-limbs then hind-limbs. Our next step is to investigate the squirrels' mechanisms of compliance estimation and the possible role of learning in deciding when to leap.

136.2 HUNTER, AH*; ANGILLETTA, MJ; PAVLIC, T; WILSON, RS; The University of Queensland, Arizona State University; *r.wilson@uq.edu.au*

Applying optimal performance theory to the soccer penalty: identifying the best strategies for success

The effort one puts into any motor task affects the intensity of the activity, its time to completion, and probability of success. By utilizing optimality theory, one can provide quantitative predictions of optimal motor effort and strategy across different ecological contexts - whether this is for animals in natural populations or humans in sporting competitions. We applied this method to identify the best strategy for soccer penalty takers given there is a trade-off between kicking speed (effort) and the accuracy of ball placement. Maximizing the probability of scoring a penalty can be a key determinant of individual and team success. In the English Premier League, a penalty is awarded approximately every 4 games and 50% of World Cup Finals since 1996 have been decided by either a penalty during the match or a penalty shoot-out. We quantified the relationship between kicking speed and accuracy for more than 20 subjects. Each subject executed more than 500 kicks at a target a distance of 11 metres (penalty distance). From these data, a function was developed for each subject describing how variance in accuracy changes with ball speed. Estimates of goal-keeper movement were also developed relative to ball speed. Using these two parameters, we developed a model to predict the probability of scoring a penalty across a range of ball speeds and target locations. We discuss the implications of our model and approach for optimal performance strategies in natural animal populations and other sports.

P2.231 HUNTER, AH*; ANGILLETTA, MJ; PAVLIC, T; WILSON, RS; The University of Queensland, Arizona State University; *r.wilson@uq.edu.au*

Soccer Penalties: Optimising strategies between competing agents

The outcome of any interaction between competing agents is determined by the physical capabilities of each combatant and the strategy they employ - whether this is for animals in natural settings or humans in sport. By measuring physical capabilities and defining strategies for both parties in a dyadic duel, we can see how these interact to determine the probability of success for each individual. Applying optimisation theory within a game-theoretic context allows us to identify the strategy for each individual that maximises their probability of success. We have used soccer penalties as a model system. For shooters, the relevant physical capabilities are their kicking accuracy across a range of speeds and their strategy can be defined by where they aim, how fast they kick and how much deception they use. For goal-keepers, their physical capabilities are their speed of movement and ability to predict shot direction, and their strategy can be defined by when they choose to dive relative to the ball being kicked and their choice of direction. We have experimentally measured these variables and developed a model that identifies the optimal strategy for both shooters and goal-keepers. Throughout this project a number of interesting performance trade-offs have been investigated - How does speed affect accuracy? Does kicking the ball harder make the shooter more predictable? Does using deception really work - does it decrease accuracy? We discuss the implications of our results for both soccer penalties and other games between competing agents when there are trade-offs between performance traits.

122.4 HURLEY, LL*; MCDIARMID, CS; ROWE, M; GRIFFITH, SC; Macquarie University, University of Sydney, University of Oslo; *laura.hurley@hdr.mq.edu.au*

The Heat is On: Decrease in Avian Sperm Functionality at High Ambient Temperatures

The impact of temperature on avian reproduction has been investigated from several angles, most recently focusing on shifts in phenology in relation to climate change. The major focus of these investigations has been on changes to egg laying and hatching dates, whereas changes in male fertility levels with environmental conditions remain largely unexplored. For birds, the role of temperature in mediating changes in sperm motility has only been evaluated in the context of artificial insemination. This ignores the potential impact that high ambient temperature may have on sperm stored just under the skin in the seminal glomerulus of passerine species. In the wild, zebra finches (*Taeniopygia guttata*) are known to suppress breeding in the hottest months of summer, and following short intense heatwaves (sustained periods > 40°C). To investigate the possibility that a reduction in sperm function might constrain reproduction in extreme heat conditions, we looked at changes in sperm motility and morphology over an experimental two-week heat exposure of 30° or 40°C in captive birds. Compared to the 30°C birds, males housed at 40°C showed consistently higher cloacal temperatures (averaging 2°C warmer). They also exhibited a decrease in average sperm swimming speed and the proportion of motile sperm across time, and a significant increase in the percentage of abnormal sperm. Our laboratory results are consistent with results we obtained from wild, free-living zebra finches breeding during a short-term heatwave (i.e. 3 days of 40-43°C). Our findings suggest that high climatic temperatures could potentially reduce fertility and limit the length of the breeding season of birds by impacting sperm quality. These results are particularly relevant in the context of an increasing frequency of heat waves resulting from climate change.

P2.229 HUSAK, JF*; HANOVER, AM; FERGUSON, HA; LOVERN, MB; Univ. of St. Thomas, Oklahoma State University; *jerry.husak@stthomas.edu*

Maternal Exercise Affects Egg-yolk Steroids in Lizards

The environment that a mother experiences while carrying young can have dramatic effects on the phenotype and fitness of her offspring. One mechanism that can cause such effects is the transfer of maternal steroid hormones to offspring either through the placenta or deposition into egg yolk. While the effects of stressors on transfer of glucocorticoids (GCs) to egg yolk have been well studied, we know less about how more subtle increases in maternal GCs may impact egg hormone levels. We examined how moderate increases in maternal GCs due to exercise training affect levels of corticosterone in egg yolk. In mammals, maternal exercise typically has positive influences on offspring physiology, but there are mixed results among studies, and we know very little about how maternal exercise affects non-mammals or oviparous species. We manipulated diet and allocation of resources to performance, via exercise training, to examine how steroid hormones change in mothers, as well as how hormones were deposited in egg yolk. Captive green anole lizards were assigned to one of four treatment combinations across two factors (diet restricted or not and endurance trained on a treadmill or not) over the course of nine weeks. Previous work showed that endurance training resulted in dramatic performance enhancement but at a cost to immune function and reproductive output. Training resulted in increased female corticosterone levels, but diet restriction resulted in reduced testosterone levels. Here we sought to determine whether these effects translated into correlated differences in egg yolk steroid profiles. Matching maternal activity (i.e., exercise) with circulating GC levels makes energetic sense, and matching offspring GC exposure in ova may be a mechanism to match offspring activity to an environment that requires increased activity.

P1.23 HUYCK, TL*; MBARANI, IM; WATSON, WH; NEWCOMB, JM; New England College, University of New Hampshire; *thuyck_ug@nec.edu*

Localization of the Circadian Clock in the Nervous System of the Mollusk Melibe leonina, using in situ Hybridization

Circadian rhythms are repeated patterns of behavior with a 24-hour period. A number of genes, including *clock*, *period*, and *type I* and *type II cryptochrome*, are responsible for producing circadian rhythms by creating a 24-hour negative feedback cycle. Previous work in our lab resulted in obtaining the RNA transcript sequences for the aforementioned circadian genes in the mollusk *Melibe leonina*, which exhibits circadian rhythms of locomotion. Based on these sequences, we had custom, fluorescently-tagged RNA probes developed by Biosearch Technologies, and used these probes in fluorescent in situ hybridization experiments. All four probes consistently labeled the same two neurons in the middle of each cerebropleural ganglion, as well as a group of 20+ neurons in the anterolateral portion of each pedal ganglion. The consistent and overlapping labeling between all four RNA probes suggests that these labeled neurons comprise at least a portion of the putative circadian clock in *Melibe*.

113.1 IHLE, KE; Smithsonian Tropical Research Institute; *kateihle@gmail.com*

Links between ovary status, sensory perceptions and foraging in a socially plastic bee

The ground plan hypotheses of social evolution argue that the complex divisions of labor observed in eusocial insect societies evolved via the compartmentalization of linked components of an ancestral reproductive cycle into different reproductive and behavioral classes. In some highly social bee species high sensory responsiveness and highly expressed reproductive characters have been linked with pollen collection. Larvae are primarily provisioned with protein rich pollen or pollen-derived material, and the reproductive ground plan hypothesis suggests that these connections are derived from an ancestral linkage between foraging behavior, sensory perception and the reproductive cycle of a solitary female. However, very little is known about such pleiotropic trait associations in less social and solitary bees, which can be used to approximate the solitary ancestors of honey bees and other eusocial lineages. I tested the links between sucrose responsiveness using the proboscis extension reflex (PER) assay, ovarian development and foraging behavior in the facultatively communal orchid bee *Euglossa hyacinthina*. Orchid bees are particularly interesting for the study of social evolution, as they are the only corbiculate bees that do not display complex social behavior. I found that bees with more developed ovaries were more likely to forage for pollen and were more responsive to sucrose. These findings lend support to the reproductive ground plan hypothesis and demonstrate that further research with orchid bees into the mechanistic regulation of behavior can provide important insights on social evolution.

P2.122 IKAGAWA, RM; KAHN, PC; LARSEN, EM*; FOWLER-FINN, KD; BOYER, SL; Macalester College, St Louis University; *boyer@macalester.edu*

Catch her while you can: Increased mating activity as the season progresses in an Eastern North American harvestman, Leiobunum ventricosum (Arachnida, Opiliones, Eupnoi)

Reproductive behavior in animals can vary seasonally, potentially in part because of seasonal changes in selection pressures on males and/or females. We examined seasonality in mating behavior in a North American species of Opiliones in the *Leiobunum* clade (animals commonly known as daddy longlegs or harvestmen), for which little is know about behavior or ecology. In general, species in this clade mate face to face, with the male inserting a penis into the female genital opening. Males may chase females prior to mating and guard them afterwards. We provide the first formal description of mating behavior in *Leiobunum ventricosum*, and test for seasonality in behavior. We collected males and females from a population in Inver Grove Heights, MN in mid-June, the middle of their mating season. They were housed overnight in the lab, and the following day we ran male-female mating trials. We ran a second set of mating trials 15 days later, and then compared the precise timing, frequency, and sequence of mating behaviors between the mid- and late-June trials (e.g., male attempts to mate; female resistance to mating; eversion, insertion, and withdrawal of penis; and male guarding). We found significant increases in male mating attempts, successful copulations, the duration of male mate guarding, and female resistance to male mating attempts. These seasonal shifts in mating behavior may reflect changes in selection due to decreased mate availability later in the season, when we have observed decreased population density in the field. Notably, male attempts and female resistance suggest increased conflict in mating interests in the sexes as the season progresses.

P2.202 IKAGAWA, RM*; LARSEN, EM; KAHN, PC; ANDERSON, MD; Macalester College; *rikagawa@macalester.edu*

Microhabitat Preferences of Harvestmen (Arachnida, Opiliones) in a Minnesota Oak Woodland

While general ecological preferences have been observed for Opiliones (harvestmen or daddy longlegs), few studies have been conducted on the microhabitat preferences of the species from the Midwestern United States. In our study, we aimed to determine the microhabitat preferences of Minnesota harvestmen in terms of vegetation cover, canopy cover, plant species, and distance to the nearest tree. Over two weeks in July 2016, we surveyed an oak forest habitat in Inver Grove Heights, MN, gathering data in each of 182 quadrats about the number of harvestmen found, species identity, distance to the nearest tree, and the diameter at breast height of that tree. We found seven different species in our survey: *Leiobunum aldrichi, L. calcar, L. politum, L. ventricosum, L. vitattum, Odiellus pictus*, and *Odiellus* sp. The data we collected were compared with data on the vegetational composition of each quadrat. We found a positive and significant relationship between abundance of a group of three species (*Leiobunum ventricosum, L. vitattum,* and *L. calcar*) and total plant species richness (excluding ferns), total plant cover, and total common buckthorn cover. A positive and significant relationship was also found between abundance of *Odiellus* species and canopy cover, likely reflective of their observed preference for leaf litter habitats. The low R^2 values indicate that though significant relationships do exist there may be many components that go into microhabitat preferences that have not yet been observed, such as humidity or temperature, and/or that these animals are microhabitat generalists.

P1.33 IMHOFF, VE*; ANDERSON, C; GUMM, JM; CLOTFELTER, E; Stephen F. Austin State University, University of Alabama, Amherst College; *imhoffve@sfasu.edu*

The visual ecology of a New World cichlid

Despite African cichlids being a classic system for understanding molecular adaptation of visual systems to the environment and coevolution of color signals and receivers' visual physiology, not much is known about visual ecology of New World cichlids. We investigate the visual system of convict cichlids, Amatitlania nigrofasciata and A. siquia using physiological and genetic methods. The convict cichlid is native to Central American, where A. siquia lives in streams and rivers of Costa Rica and A. nigrofasciata lives in lakes in Nicaragua. Using microspectrophotometry, we establish that each species expresses 4 different cone photoreceptors. Further, sequencing of opsin genes expressed in the retina confirms that A. nigrofasciata expresses at least 4 opsin genes (SWS2a, SWS2b, Rh2a, and LWS). This conflicts with a previous report that found no evidence of Rh2 expression in the retina. Finally, we compare opsin sequences from populations of A. nigrofasciata that occur in different light environments. Preliminary evidence did not find differences in opsin sequences between populations, suggesting that visual adaptation between populations may be due to gene expression profiles, as in some African cichlid systems.

P1.263 INGERSOLL, R*; LENTINK, D; Stanford University; *riversi@stanford.edu*

How Hummingbirds Lift Bodyweight During Hovering Flight

Both hummingbirds and insects hover with flapping wings to forage, a remarkable example of behavioral convergence despite profound differences in body plans. For efficiency, insects rely on elastic recoil to beat their wings back and forth and lift their bodyweight symmetrically over the downstroke and upstroke. The question of whether hummingbirds also harness elastic recoil has resulted in a multi-decade quandary. Furthermore, asymmetry in the avian flight apparatus is thought to severely restrict the hummingbird's ability to support bodyweight during the upstroke. Here we present *in vivo* recordings of aerodynamic force in hovering Anna's hummingbirds using a novel aerodynamic force platform. Additionally, we determined the required muscle torque and power by integrating wing morphology, kinematics, and force measurements with improved aerodynamic models. The new method is applicable to measure forces of flying animals and robots in general.

P3.174 IONESCU, A.*; WINWARD, J; JIMENEZ, A.G.; Colgate University; *ajimenez@colgate.edu*

The effect of aging on cellular metabolic rates in domestic dogs

Small mammals tend to have shorter lifespans and lower whole animal metabolic rates, whereas large mammals typically have longer lifespans and higher whole animal metabolic rates. However, domestic dogs, *Canis lupus familiaris* , are an anomaly: small breed dogs have lower whole animal metabolic rates, yet they have longer lifespans compared with large breed dogs that have higher whole animal metabolic rates, but shorter lifespans. In this study, we looked at cellular metabolic rates as small breed and large breed dogs age. Primary dermal fibroblasts were isolated and grown in tissue culture from skin samples that were obtained from veterinarians. We measured basal oxygen consumption, proton leak, maximal oxygen consumption, non-mitochondrial oxygen consumption and rates of glycolysis using a Seahorse XF96 oxygen flux analyzer. Our results show basal oxygen consumption, proton leak, maximal oxygen consumption and non-mitochondrial respiration in small breed dogs had increased rates as they aged, whereas, we see the opposite pattern in large breed dogs showing a decrease in rates of all parameters of cellular oxygen consumption as they age. We see that as both size classes age, rates of glycolysis tend to increase. This implies that in large breed dogs there is a reduction in oxygen consumption pathways with age, indicating that they are relying less on oxidative phosphorylation as the main source of ATP production in cellular respiration, a trend that may suggest that older dogs cannot produce ATP at the same efficiency as they did at a younger age. Additionally, increases in cellular oxygen consumption in large breed puppies may increase RS (reactive species) production, thus, increasing the amount of cellular damage that happens early on in large breed dogs, potentially explaining their shorter lifespans.

122.3 IRVINE, SQ*; LOPEZ, C; Univ. of Rhode Island; *sirvine@uri.edu*

Proteomic Changes Due to Elevated Temperature in Ascidian Ovaries

Ciona intestinalis, a common sea squirt, exhibits lower reproductive success at the upper extreme of water temperatures it experiences in coastal New England. In order to understand the changes in protein expression associated with this temperature stress, and possible response to global temperature change, we reared *C. intestinalis* from embryos to adults at 18°C (the highest temperature at which they reproduce normally at our collection site in Rhode Island) and 22°C (to simulate the temperatures they might experience due to climate change). We then dissected ovaries from animals at each temperature, extracted protein, and measured proteomic levels using shotgun mass spectrometry (LC-MS/MS). 1616 proteins were detected at a 1% false discovery rate present in both temperature groups by our LC-MS/MS method. 85 of those proteins are considered up or down regulated according to various criteria. Principal component analysis shows a clear distinction in protein expression pattern between the control (18°C) group and "stressed" (22°C) group. Similar to previous studies, cytoskeletal and chaparone proteins are clearly upregulated in the high temperature group. Notably, several transport and signaling proteins, not previously found to be related to temperature stress, are prominent among both up and down regulated proteins.

32.3 ISAACS, MR*; HENSEL, S; LEE, DV; Univ. of Nevada, Las Vegas, Technische Universität Darmstadt; *michael.isaacs@unlv.edu*

Effects of decreased heel deflection on a passive walking prosthesis

This study explores the effect of heel deflection on whole body walking dynamics of persons with a unilateral transtibial amputation using a passive prosthetic, the Cheetah Xplore by Össur. After a baseline kinetic and kinematic data collection was completed, the user's prosthesis was modified by the installation of a 4 mm wedge between the "heel" and the C-arm of the subject's device. This mechanical obstruction decreased the range of deflection of the carbon fiber components of the prosthesis during the heel strike of the step-to-step transition. The subject repeated the protocol with the modification and the mechanical cost of transport (CoT_{mech}) for the two conditions was compared at different dimensionless velocities within the walking speed range. Slow, moderate, and fast walking speeds were prescribed to the participant for both the high and low deflection conditions to control for speed effects. The recorded data was utilized to determine the planar orientation of the force (**F**) and velocity (**V**) vectors of the CoM in every instance of the stride. A near perpendicular arrangement of **F** and **V** minimizes the CoT_{mech} for steady speed walking. With this assumption in mind, the effectiveness of cooperating limbs is addressed with a novel assessment of the interlimb work done by the legs on the CoM during double stance. This type of analysis highlights potential deficiencies in the affected limb's step that are translated into the body dynamics and are quantifiable at the CoM level using the method we propose. The presentation will demonstrate the effectiveness of the new technique in whole body dynamics assessment, and will substantiate the importance of compliant mechanisms in prosthetic devices designed with the intention to restore human walking dynamics.

P3.172 ISABELLA, I*; MCCUE, M/D; St. Mary's Univ; *mmccue1@stmarytx.edu*

The postabsorptive and postprandial metabolic rates of praying mantises: comparisons across species, body masses, and meal sizes

The metabolic rate of an animal affects the amount of energy available for its growth, activity and reproduction and, ultimately, shapes how energy and nutrients flow through ecosystems. Standard metabolic rate (SMR; when animals are post-absorptive and at rest) and specific dynamic action (SDA; the cost of digesting and processing food) are two major components of animal metabolism. SMR has been studied in hundreds of species of insects, but very little is known about the SMR of praying mantises. We measured the rates of CO2 production as a proxy for metabolic rate and tested the prediction that the SMR of mantises more closely resembles the low SMR of spiders - a characteristic generally believed to be related to their sit-and-wait foraging strategy. Although few studies have examined SDA in insects we also tested the prediction that mantises would exhibit comparatively large SDA responses characteristic of other types of predators (e.g., snakes) known to consume enormous, protein-rich meals. The SMR of the mantises was positively correlated with body mass and did not differ among the four species we examined. Their SMR was best described by the equation uWatts = 1526 * grams$^{0.745}$ and was not significantly different from that predicted by the standard ‘insect-curve'; but it was significantly higher than that of spiders to which mantises are ecologically more similar than other insects. Mantises consumed meals as large as 138 % of their body mass and within 6-12 h of feeding and metabolic rates doubled before gradually returning to prefeeding rates over the subsequent four days. We found that the SDA responses were isometrically correlated with meal size and the relative cost of digestion was 38 % of the energy in each meal.

P1.19 ISMAILOV, II*; SCHARPING, JB; ANDREEVA, IE; FRIEDLANDER, MJ; Virginia Tech Carilion Res. Institute, Virginia Tech Carilion Sch. of Med.; *Ismailov@vtc.vt.edu*

Behavioral and Neural Responses to Warming in Antarctic Fishes

Stenothermic teleosts *C. aceratus* (lack hemoglobin, Hb-) and *N. coriiceps* (possess hemoglobin, Hb+) live on the Antarctic shelf at ~0&degC. Hb- fishes are less tolerant to rise in temperature (T) than Hb+ animals. As part of a larger effort to investigate underpinnings of this difference (see Biederman, Crockett, this meeting), our study examines the neural component of thermal tolerance of these fishes. Freely swimming fishes responded to ambient warming in a biphasic manner, with an increase in motoric behaviors (MB) followed by a decline until loss of equilibrium (LE) occurred (onset temperature (OT) ~14&degC in Hb- and ~16&degC in Hb+). Both fishes increased locomotion (OT ~6&degC in both species, peak at ~9.5&degC in Hb- and ~11&degC in Hb+) and displayed bilateral pectoral fin movement without motion (OT ~6degC in Hb- and ~10&degC in Hb+, diminishing before LE). Maladaptive MB of *N. coriiceps* included fin and body jerks (OT ~6.5&degC) and were all biphasic. *C. aceratus* displayed no maladaptive MB until seconds before LE. Local warming of the cerebellum in anesthetized fishes resulted in biphasic (an increase followed by a decline) changes in Purkinje cell (PC) action potential firing rate and pattern, with no differences between Hb+ and Hb- species. Irrigation of anesthetized fishes with warmed water (with the cerebellum chilled) led to a decline in PC firing rate in both species (OT lower in Hb+ than in Hb-), followed by cessation of spiking (OT not different between the species). We conclude that a central neural component is involved in responses of both Hb- and Hb+ fishes to warming, and is more susceptible to T elevations in Hb+ species. The relationships between constituents of this component are yet to be determined. Supported by NSF ANT-1341602.

P1.222 IVANINA, AV; FALFUSHYNSKA, HI; SOKOLOVA, IM*; University of North Carolina at Charlotte, Charlotte, NC, USA , I.Ya. Horbachevsky Ternopil State Medical University, Ternopil, Ukraine, Department of Marine Biology, University of Rostock, Rostock, Germany; *inna.sokolova@uni-rostock.de*

BIOMINERALIZATION-RELATED SPECIALIZATION OF HEMOCYTES AND MANTLE TISSUES OF THE PACIFIC OYSTERS CRASSOSTREA GIGAS

Molluscan shells are mineral-organic composites with unique structural organization, and mechanical properties superior to geologic calcium carbonates. Outer mantle edge cells (OME) has been linked to biomineralization due to their proximity to the shell surface and ability to maintain shell deposition ex vivo, while other studies indicate that hemocytes (HCs) may also contribute to the shell building. However, the specific roles and interactions of these two cell types are unknown. We isolated four different fractions of HCs on a density gradient, and compared their gene expression profiles with the OME. Two HC fractions (H1 and H4) consisted of cells with long filamentous pseudopodia, had the highest adhesion capacity and motility of all HCs and presumably contained immune cells. HC fractions H2 and H3 consisted of irregularly shaped cells with no filamentous structures. These hemocytes had high levels of expression of ion regulatory genes and select matrix proteins (fibronectin Prot3, and fibronectin-ankyrin) as well as high intracellular [Ca2+] levels (in H2 fraction). OME had the highest expression of matrix proteins including silk-like protein and fibronectin Prot2, as well as chitin synthase II, the vascular endothelial growth factor (VEGF) and VEGF receptor. Our data indicate that H2 and H3 subpopulations of HCs play a role in biomineralization together with OME, and that HCs and OME specialize on different biomineralization-related functions. Supported by NSF IOS award 1557870.

104.6 IVANINA, AV*; PHIPPEN, BL; OLIVER, JD; SOKOLOVA, IM; University of North Carolina at Charlotte, Charlotte, NC, USA, University of Rostock, Rostock, Germany; *inna.sokolova@uni-rostock.de*

Combination of anoxia and Vibrio coralliilyticus lead to immune disruption in the Eastern oyster, Crassostrea virginica

An important coral pathogen *Vibrio coralliilyticus* causes infection of fish and shellfish, including Eastern and Pacific oyster larvae. This bacterium was the cause of multiple recent hatchery crashes in Oregon and Washington states, although its impact on adult oyster populations is not yet clear. The extent of the coastal dead zones is increasing with global warming which can increase oysters' vulnerability to the pathogen. We examined the effects V. coralliilyticus infection on oysters under normoxic and anoxic conditions including host mortality and immune response and expression of genes involved in virulence and intracellular signaling of the pathogen. The combination of *V. coralliilyticus* and anoxia resulted in 100% mortality after 6 days of exposure, where 100% of oysters survived 18 days of exposure to anoxia or bacterial stress alone. Concomitant anoxia and pathogen stress resulted in a significant increase in the hypoxia inducible factor, lectin, and key antioxidant enzymes in oyster immune cells. Anoxia exposure led to a significant increase of the expression of a zinc-metalloprotease (vcpA) in *V. coralliilyticus*. Expression of other putative virulence factors (hemolysin and flagellum) was higher in normoxia. This indicates that different virulence factors are activated in normoxia and anoxia possibly contributing to differential mortality of the hosts. Our findings show the importance of *V. coralliilyticus* as a potential pathogen for adult oysters and the potentially virulence-enhancing effects of anoxia via increased intracellular signaling enhancing hosts' morbidity and mortality.

79.3 IVANOV, B.M.*; MURPHY, T.G.; JOHNSON, M.A.; Trinity University ; *bandre@trinity.edu*

Green Anoles, Brown Bodies: Does the "Loser Effect" Influence Dorsal Coloration in Lizards?

For many animals, winning agonistic interactions with conspecifics is critical for obtaining necessary resources. Although competitive success may be dependent on differences in resource holding potential, previous social experience can also alter an individual's investment in future fights, giving rise to winner-loser effects. Male green anole lizards often engage in aggressive interactions mediated by visual displays, including dewlap extensions, push-ups, and changes in body color between green and brown. Here, we investigated whether dorsal coloration is altered due to competitive losses. We conducted a series of loser effect trials in which we tested if previous experience in losing makes a lizard more likely to exhibit a brown coloration and to lose subsequent encounters. Sixteen male lizards were "trained" to lose agonistic interactions by pairing them with a series of trainer males (assigned to maximize the differences in each pair in mass, snout-vent length, and head size) for one hour on each of three consecutive days. Following these trials, focal males competed with a size-matched, novel male to test for a loser effect. Eight of these trials yielded a clear loser in which 7 focal males lost and 1 focal male won, suggesting the presence of a loser effect. Individuals that were more often brown prior to the trials were more likely to lose in the training trials, supporting our previous findings that predominant body color is predictive of the outcome of agonistic interactions. Also, the predominant body color of lizards that lost their fourth trial was more likely to become brown after this final interaction. These results indicate that competitive experiences affect both behavior and appearance of green anoles.

P1.109 JACKSON, J. M.*; LOZIER, J. D. ; PIMSLER, M. L.; DILLON, M. E.; STRANGE, J. P.; University of Alabama, University of Wyoming, USDA-Utah State University; *jjackson10@crimson.ua.edu*

Investigating genomic patterns of adaptation and gene flow in montane bumble bees

Montane environments provide particularly good settings in which to investigate factors that generate and maintain biodiversity. Their landscapes are heterogeneous, containing non-uniform terrain and a mosaic of different habitat types. Clines in elevation, temperature, season length, moisture regimes, and other variables can create complex patterns of both adaptive and neutral genetic variation on the landscape. We investigate these patterns in the bumble bee *Bombus vosnesenskii* within the Sierra-Nevada and Cascade mountain ranges of California, Oregon, and Washington. Bumble bees interact with the environment in numerous ways that are affected by the unique environmental qualities in montane systems, including spatial variation in floral resources, temperature, air density, precipitation, and seasonality. We use single nucleotide polymorphism data generated by high-throughput RADtag sequencing to examine genomic patterns of adaptation and demography across this complex landscape. Results will have implications for our understanding of interactions between gene flow and local adaptation in genomic divergence in heterogeneous landscapes.

109.5 JACKSON, LM*; FERNANDO, P ; HANSCOM, J; BALHOFF, JP; MABEE, PM; University of South Dakota, RTI International, Research Triangle Park; *laura.jackson@usd.edu*

Automated Integration of Phenomics And Phylogenetic Data To Investigate Paired Fin Evolution Across Teleost Fishes

How often—across all 30,000+ species of teleost fishes—were pectoral and pelvic fins lost? Are they ever regained? Surveying the literature for information about the taxonomic distribution of any morphological feature is a laborious and time-consuming manual task. We show that tagging anatomy with computer-readable terms automates this process, enabling rapid views of integrated data, and extending author observations to include inferred data. We compiled an extensive literature-based character survey of paired fin loss across extant teleost fishes, and demonstrate that paired fin data can be automatically extracted as a matrix from anatomical data that has been "tagged" with computer-readable terms in the Phenoscape Knowledgebase (kb.phenoscape.org). Using an automated bioinformatic approach to infer and propagate our data, we are able to extend our knowledge from what was previously documented in the literature. We have created computational methods that allow us to merge these data with a species-level tree for all teleosts from the OpenTree of Life, a difficult challenge at this scale, which enabled us to document the evolutionary gain and loss of paired fins. Broad-scale phylogenetic mapping of morphological traits across all extant fishes has rarely been done, but it can be a helpful research tool for future studies. Applying semantic logic to produce new inferences of anatomical parts in a phylogenetic context can increase our ability for data integration and comparative studies. In addition, morphological data with its links to genetics has the potential to offer powerful insights into the evolutionary process.

3.1 JACOBS, MW*; BAYER, SR; McDaniel College, Univ. of Maine; *mjacobs@mcdaniel.edu*

Effects of postlarval experience on settlement behavior in postlarval and juvenile lobsters, Homarus americanus

Recruitment is likely a significant bottleneck for lobster populations in the Gulf of Maine, as a result of intense predation on juveniles and limited availability of shelter in appropriate benthic habitats. During settlement, lobster postlarvae transition from a roving, exploratory planktonic lifestyle to a very cryptic, benthic one. Behavioral transitions during this stage are critically important for successful settlement, and may be influenced by a wide variety of developmental and environmental factors. During the postlarval stage (stage IV), we examined variation in settlement behavior as a function of age from hatching, age from metamorphosis, and early postlarval experience. The behavioral transition was surprisingly abrupt: the majority of postlarvae transitioned to benthic, cryptic behavior immediately after metamorphosis. There was no effect of early postlarval experience or developmental history on the timing of the behavioral transitions. We found clear evidence of a behavioral carry-over effect between the postlarval and early juvenile (stage V) stages, but not the one we predicted: juveniles with postlarval shelter experience took significantly *longer* to locate and settle into shelters. Juveniles with prior shelter experience may be more exploratory, or more selective about settlement location. Our results suggest that the behavioral transition from pelagic/exploratory to benthic/cryptic during the postlarval settlement stage is innate - tightly coupled to the molt cycle, but not strongly influenced by postllarval experiences or environment. However, postlarval experiences during the settlement stage do carry over and influence sheltering behavior during the first juvenile stage.

60.7 JACOBS, C*; HOLZMAN, R; Tel Aviv University, Israel; *cnjacobs@coastal.edu*

The Diversity of Suction Feeding Performance Across Teleosts: a PIV Study with 16 Species

Suction feeding is the most common feeding strategy across teleosts. It is expected that the morphological and functional diversity between fish species are driven by the need for unique suction feeding strategies that arise from trophic disparity. However, very few studies empirically measured the suction induced flow field, in only 3 species. Here, we used particle image velocimetry to examine temporal and spatial patterns of suction-induced flows in 16 teleost species, expanding across the teleost tree of life, representing species with diverse morphologies, mouth sizes (ranging 1.3-21 mm), dentition, and kinematics. We asked if suction flows scale with mouth, whether species that produce faster flows have slower ram speed, and whether the decay of suction flow is consistent across species. A significant relationship was found between maximum gape size and maximum flow speed both within and between species. However, while a positive inter-species relationship between gape size and flow speed was observed, intra-species relationships included positive, neutral and negative correlations among these factors. Norton and Brainerd (1993) famously suggested a tradeoff between ram speed and suction flows. However, we found a non-significant relationship between ram speed and maximal flow speed for any species or the collective and thus refute this hypothesis. Lastly, our results show a conserved spatial flow pattern across species. Flow speeds decayed exponentially as a function of distance from the mouth, with flow decaying to 5% at a distance of one mouth diameter for all species, indeterminate of gape size or flow speed. Our findings demonstrate immense diversity in flow speeds and influencing factors, despite a conserved spatial pattern in suction flows.

P2.247 JACOBS, M*; AHEARN, GA; Univ. of North Florida, Jacksonville; *mariaflorajacobs1@gmail.com*

Effects of variable pH on calcium uptake by river white shrimp Penaeus setiferus gills

Dissolved atmospheric CO2 reacts with seawater to form carbonic acid and protons, resulting in acidification of seawater. Increased proton concentration results in dissociation of skeletal calcium carbonate, and the protonation of carbonate into bicarbonate, which is incompatible with binding to calcium to form calcium carbonate skeletons that are essential to marine life. Freshwater acidification is equally important to investigate for the animals that live there. This project examines the effects of water pH on the uptake of radioactive 45Ca by gill vesicles of a freshwater animal. River white shrimp, Penaeus setiferus, were obtained from water with a salinity of 5 ‰ and a pH of approximately 7. Partially purified plasma membrane vesicles (PMV) from shrimp gills were prepared through a homogenization and centrifugation process. Protein concentration of the vesicles was determined using a Bradford protein assay. The resulting PMV were loaded with a pH 8 mannitol buffer. PMV uptake of 45Ca at 50 µM was measured in triplicate experiments using external pH conditions in mannitol buffer adjusted to pH 8, 7, and 6 for four time periods of 1, 5, 20 and 30 minutes. Transport into gill vesicles as pmol/mg protein x min was a linear function of time and was greatest at pH 7. 45Ca uptakes at pH 6 and 8 were not significantly different from horizontal lines, suggesting that calcium transport was abolished. These tentative results suggest that environmental pH of 7, where the shrimp naturally occurs, was similar to the pH where maximum calcium uptake took place. Furthermore, small changes in environmental proton concentration may inhibit the uptake of calcium from water and potentially affect calcification in these freshwater crustaceans.

43.3 JACOBS, D/K*; DOLBY, G/A; HECHINGER, R; LORDA, J; ELLINGSON , R; FINDLEY, L; UCLA, Scripps Inst., UCSB, CIAD, Guaymas; *djacobs@ucla.edu*

Sea-level cycles generate glacial age refugia on subtropical coasts

Bathymetry-based models of shoreline habitat suggest that there were no settings where substantial tidal estuaries could form during glacial lowstand on the Pacific Coast between a region north of Pt Conception in California and the Viscaino region just north of Pta Eugenia in the middle of the Baja California coast. We complement this bathymetric modeling approach, with analysis of microsatellite-based genetic mixing in three estuary specialist fishes with limited dispersal- *Fundulus parvipinnis* (killifish), *Quietula y-cauda* (shadow goby), and *Gillichthys mirabilis* (long-jawed mudsucker). Using the alleles that discriminate between refugial populations, we are able demonstrate mixing across the intervening California Bight from these refugial sources in these three fishes. The ranges of *Q. y cauda* and *G. mirabilis* extend into the Gulf of California. As expected, Gulf populations are distinct from the outer coast, but populations are also geographically subdivided within the Gulf. Through similar application of paleo-habitat modeling and study of genetic admixture we document a set of glacial age estuarine refugia within the Gulf. Local glacial refugia and subsequent mixing between isolated habitat is evident on the steeper western side of the Gulf. While the shallowly sloping topography/bathymetry on the mainland side of the Gulf exhibits greater habitat and genetic continuity. These observations suggest that glaciation strongly influences evolutionary processes on tropical coasts with heterogenous habitat far removed from glaciation itself. These processes and this history should be considered as humans institute a new round of sea-level rise and simultaneously hope to preserve the biodiversity of our coasts.

P2.124 JACQUEZ, A. A.*; SASSON, D. A.; RYAN, J. F.; Whitney Laboratory for Marine Bioscience; *anya_jacquez@yahoo.com*

Reproductive behaviors in the simultaneous hermaphrodite Mnemiopsis leidyi (Ctenophora) with implications on the rate of self-fertilization

Mnemiopsis leidyi is a ctenophore (comb jelly) native to near-shore environments along the Atlantic coast of the Americas. These planktonic predators occupy significant roles within the food webs of their native habitats, as well as in European waters where they are invasive. Despite their ecological impact, the reproductive biology of *M. leidyi* is not well studied. Most ctenophores, including *M. leidyi*, are simultaneous hermaphrodites capable of self-fertilization. Recent work has shown that self-fertilization leads to inbreeding depression through reduced offspring viability in *M. leidyi*. This raises the question: What strategies do *M. leidyi* employ to avoid inbreeding costs associated with self-fertilization? In this study, we investigate one potential strategy - egg trading. Egg trading is a behavior seen in some simultaneously hermaphroditic animals where individuals of mating pairs alternate between releasing eggs and sperm. To test for the possibility of egg-trading, we placed a pair of size-matched *M. leidyi* on either side of a divided tank that allowed water to flow between the two individuals, but kept them physically separated. We found that there was an overall pattern where one side of the tank produced many more eggs than the other side and that this difference was higher than would be expected by a random sampling of the data. These results suggest that there is coordination and communication occurring between spawning pairs of *M. leidyi*, possibly used to avoid self-fertilization. These findings are important early steps towards understanding the reproductive behavior of *M. leidyi* and will provide insight into both the native and invasive ecology of these animals.

25.7 JAHN, C; LERCH, S; EIBNER, C*; Friedrich-Schiller-University Jena; *cornelius.eibner@uni-jena.de*

Cell Proliferation and Segmental Patterning are Closely Linked During Posterior Segmentation in Spiders

Although segmentation has been studied in great detail in *Drosophila melanogaster*, the simultaneous formation of segments (long germ system), as found in this fly, and the underlying mechanism appears to be a derived character. In most animals, the metameric units (segments, somites) form mainly by sequential posterior addition (short germ systems). The currently prevalent models of these processes in vertebrates and short germ arthropods rely on successive patterning of large pools of undifferentiated cells (presomitic mesoderm, posterior growth zone) by anteriorly travelling waves of gene expression. By analysing gene expression and cell proliferation, we show that posterior segmentation in the spider *Parasteatoda tepidariorum* does not involve a large pool of undifferentiated cells. Instead segmentation and cell proliferation are tightly coupled. Each new segment is made in a two-phase process of tissue generation and segment patterning. This sequence repeats itself for every new segment being formed. Furthermore, we found that the segment polarity gene Pt-hedgehog is one of the earliest genes involved in this process. To our knowledge, this is the first report of a role of hedgehog in segmentation upstream of its highly conserved role as a segment polarity gene. Expression analysis of pair-rule gene and gap gene orthologues further supports that segments are patterned individually at the place of their tissue origin in a process of expression domain refinement. We further demonstrate that the gap gene orthologues Pt-krüppel1 is involved in this process. Posterior segmentation in spiders thus represents an alternative way to the canonical model of short germ segmentation at the base of the arthropods.

17.7 JAKOBI, T*; RAVI, S; KOLOMENSKIY, D; IKEDA, T; LIU, H; RMIT, Chiba Univ., Chiba Univ.; *timothy.jakobi@rmit.edu.au*

Battling with big blasts: bumblebees orchestrate clever flight manoeuvres in complex environments.

Flying insects confront the flight challenges of the natural environment, vanquishing many of the constraints that currently restrict bio-inspired flying robots; yet our understanding of how these challenges are overcome remains shallow. Bumblebees are fine models which exemplify the remarkable flight characteristics of flying insects, relentlessly seeking aerial triumph in their biological functions irrespective of the weather. Outdoor environments typically contain sporadic air conditions often expressed as varying air blasts or unsteady turbulent flows irregular in direction. We examined the body dynamics of bumblebees (*Bombus ignitus*) flying through a single discrete gust such that a high-speed air-sheet discharges across a vertical cross-section of the flight path. We recorded the three-dimensional rotations and translations for three separate gust orientations: (1) horizontal; a sideways air disturbance (2) vertical; an upward disturbance and (3) vertical; a downward disturbance. In all three gust instances, bees were able to successfully traverse through the disturbance without crashing. In a sideways gust, bees were displaced more severely and executed higher magnitudes of acceleration, reaffirming greater lateral sensitivity of bumblebees. The upward gust caused the least disruption to steady displacements, rates and accelerations of the bees. In stark contrast, the downward gust was seen to elicit significant unsteady responses. It appeared to acutely affect velocity magnitude and demanded an increased number of corrective manoeuvres, despite inducing gentler accelerations and displacements than the sideways and upwards gusts. Transit times for bees flying through the downward gust were approximately double that of those flying through the upward gust, suggesting that a downward gust draws detrimental costs to flight.

P1.249 JAMISON, MP*; BURNETTE, MF; ASHLEY-ROSS, MA; Wake Forest University; *jamimp13@wfu.edu*

Big fins make for bad jumps in male Betta splendens

When one considers what makes a fish fast, it is tempting to assume that having larger fins would result in better performance: more surface area would be available to push against the water, or the substrate in a terrestrial tail-flip jump. Alternatively, it might be that excessively large fins could heighten the effect of drag in the water and also stick to the surface substrate during terrestrial jumps, ultimately hindering performance in both environments. We sought to determine how median fin size affects jumping on land and out of the water by exploiting variation in fin size in the Siamese fighting fish, *Betta splendens*. Selective breeding has produced males with large, elaborate median fins, while females retain smaller fin morphology, closer to wild type *Betta*. We used high-speed video to capture aquatic and terrestrial jumps, and measured jump duration, height and velocity with ImageJ. We made two comparisons: (1) females to unaltered males, and (2) a paired comparison of the males in their unaltered state to themselves after we had trimmed their median fins to approximately 75%, 50%, and 25% of their original area. We found that males with large, elaborate median fins exhibited poorer performance in jump duration, jump height, and maximum velocity when compared with either females or to themselves with fins trimmed. Thus, the alternative hypothesis, that increased fin size above a certain area is detrimental to jumping performance, is supported by our data. Selective breeding for ornamental form has resulted in reduced locomotor performance in male *Betta splendens.*

66.2 JAMNICZKY, HA*; LE, A; BARRY, TN; ROGERS, SM; Univ. of Calgary; *hajamnic@ucalgary.ca*

Variation in a suite of armour phenotype traits reveals a complex response to selective pressure in threespine stickleback (Gasterosteus aculeatus)

Threespine stickleback (*Gasterosteus aculeatus*) have been shown to exhibit rapid, parallel changes in armour phenotype when adapting to new habitats, including substantial reduction in plate number in association with adaptation to freshwater environments. Such skeletal changes may occur in response to ecological variables including predation pressure and foraging mode, and environmental variables including mineral availability. Here, we test the hypothesis that changes in plate number are accompanied by changes in plate shape, extent of body coverage, and bone mineral density, reflecting a complex phenotypic response to different selective pressures in changing habitats. We predict that fish inhabiting tidally-influenced freshwater habitats will exhibit increased variation in plate phenotypes present, and that these phenotypes will collectively represent decreased investment in bone production. We use 2D and 3D imaging techniques to quantify a series of armour traits from stickleback occupying three marine habitats and one tidally-influenced freshwater stream in southwestern British Columbia. We find that stickleback inhabiting marine environments share a relatively conserved plate phenotype that includes a full complement of highly mineralized plates that provide extensive body coverage, while those inhabiting a stream environment express a plate phenotype that varies markedly on all axes measured both within this population and in comparison to their marine neighbours. Our results suggest that environmental chemistry may play a role in modulating how stickleback phenotypes change in response to new environments, and further hint at an important role for development in structuring phenotypic variation during the process of adaptive change in stickleback.

5.7 JANGJOO, M*; MATTER, SF; BENOIT, JB; KEYGHOBADI, N; Univ. of Western Ontario, Canada, Univ. of Cincinnati, Ohio; *mjangjoo@uwo.ca*

Gene expression associated with dispersal ability under different temperature conditions in the alpine butterfly, Parnassius smintheus

Dispersal is a critical process affecting the dynamics, persistence and evolutionary trajectories of spatially structured populations. Flight capacity is a potentially important determinant of dispersal in animals capable of flight and, in insects, may be strongly affected by ambient and body temperature. The gene encoding the metabolic enzyme phosphoglucose isomerase (PGI), involved in providing energy for flight, is a well-endorsed candidate gene for dispersal in insects. We used RNA−seq technology to prepare an adult transcriptome for the alpine butterfly, *Parnassius smintheus*. Our goals were to (i) identify the coding sequence of *Pgi*, and (ii) profile gene expression patterns among individuals with differing dispersal histories and caught flying under different temperature conditions within a network of interconnected populations. We first pooled RNA−seq reads from all individuals to assemble a *de novo* reference transcriptome using multiple different assemblers (Trinity, CLC and Oases), and then identified the *Pgi* coding sequence. We are assessing sequence variation at the *Pgi* locus to explore whether specific genotypes are associated with flight at different temperatures and with greater dispersal. We are also conducting differential expression analysis to compare disperser and non-disperser individuals, as well as individuals captured during flight with higher versus lower body temperature as compared to air temperature. Our experimental analysis provides insights into genetic and environmental factors underlying flight and dispersal in this alpine insect.

P2.253 JANIS, B*; JANIS, S; TIPPERY, N; YAVUZCETIN, O; CHAKRABORTY, N; WONG, M; MENZE, MA; University of Louisville, University of Wisconsin Whitewater, University of Michigan-Dearborn; *Brett.Janis2015@gmail.com*

Impact of Group 3 LEA Proteins on Cellular Structure during Desiccation

Artemia franciscana is an anhydrobiotic crustacean that survives extreme desiccation, osmotic stress, and severe cold during its encysted life-history stage. During this stage, *A. franciscana* expresses intrinsically-disordered polypeptides termed late embryogenesis abundant (LEA) proteins and accumulates trehalose. Trehalose is a non-reducing disaccharide known to enter a glassy state at low water contents. To examine the impacts of LEA proteins from *A. franciscana* on cellular structure, Kc167 cells from *D. melanogaster* were transfected with one of two genes encoding for group 3 LEA proteins (*Afr*LEA2 or *Afr*LEA3m). Transgenic and control cells were desiccated in presence and absence of trehalose using anhydrous calcium sulfate and examined using scanning electron microscopy (SEM), or Raman microspectroscopy (RS). SEM demonstrated that, in absence of trehalose, cells expressing *Afr*LEA2 maintained a larger diameter compared to both control and *Afr*LEA3m expressing cells. However, cells expressing *Afr*LEA3m maintained higher degrees of membrane integrity in the desiccated state compared to both control and *Afr*LEA2 expressing cells. In presence of 100 mM or 200 mM trehalose, control cells maintained higher degrees of membrane integrity, but had a smaller diameter than in absence of trehalose. Both transgenic cell lines maintained higher degrees of membrane integrity in the presence of trehalose than control cells and maintained a larger diameter. Interestingly, transgenic cells lost more water during desiccation than control cells according to RS measurements. Our results suggest that LEA proteins significantly impact cellular structure in the desiccated state (NSF *IOS-1456809/1457061*).

105.3 JANZEN, FJ*; ADAMS, CIM; POLICH, RL; WEBER, RC; Iowa State Univ.; *fjanzen@iastate.edu*
Does Adult Sex Ratio Influence Nest-site Choice in a Turtle with Temperature-dependent Sex Determination?
Sex-ratio theory predicts that, all else being equal, mothers that produce offspring of the rarer sex engender a fitness benefit. Implementing such a strategy might be less challenging in species with environmental sex determination relative to those with genotypic sex determination. Reptiles with temperature-dependent sex determination (TSD) could conceivably choose nest sites with the thermal characteristics (e.g., shade cover) to readily overproduce the rarer sex. To test this hypothesis, we seeded three secure outdoor ponds for a two-year period with different sex ratios (3:1, 1:1, and 1:3) of adult painted turtles (*Chrysemys picta*), a reptile species with TSD. We then quantified traits related to nesting behavior that could influence offspring sex ratio, including nesting date, nest depth, and nest shade cover. Preliminary analyses revealed no relationship between the adult sex ratio treatments and any measured nest traits, thus rejecting our hypothesis. If adaptive sex allocation occurs in this system, it instead may manifest via maternal epigenetic predisposition of offspring sex or in response to a phenomenon other than adult sex ratio.

P3.95 JARAMILLO, MA*; WEBBER, MA; STEIN, CN; JOHNSON, MA; Trinity University; *mjaramil@trinity.edu*
Visual Processing of Social Displays in the Lizard Brain
Animals perform visual displays to communicate information about potential competitors, mates, predators, and prey. Behavioral responses to these complex displays have evolved as a result of the mechanisms by which visual information is processed in the brain. Here, we seek to understand how information processing differs among *Anolis carolinensis* (green anole lizards) exposed to social or non-social visual information by manipulating visual cues and measuring subsequent changes in neural activity within the visual and social nuclei of the brain. We conducted behavioral trials in which a male lizard was placed in a visually neutral arena, presented with visual information from a live anole or from carefully constructed video playback, and their behavioral responses were recorded. Each lizard (n = 40) was randomly assigned to one of four treatments - social control (two live males interacting with each other), non-social control (focal lizard shown video of a stationary perch), social condition (focal lizard shown video of a lizard displaying on a perch), or non-social condition (focal lizard shown video of a lizard displaying on a perch, but with the pixels scrambled to remove social context). Our behavioral results showed that lizards in the social treatments were more attentive to the visual information than lizards in the nonsocial treatments. Immediately after each trial, lizard brains were flash-frozen in isopentane. We are now using immunocytochemistry to measure neural activity in the visual and social brain regions by quantifying expression levels of the immediate early gene c-*fos*. From this study, we hope to gain a greater understanding of how lizards process visual and social information and the degree to which brain regions differentially respond to visual displays.

P2.32 JARDINE, LJ*; PARSONS, Z; OYEN, KJ; STRANGE, JP; DILLON, ME; Oklahoma City University, Oklahoma City, OK, University of Wyoming, Laramie, WY, USDA ARS, Logan, UT; *lejardine@my.okcu.edu*
Sex differences in chill coma recovery times of bumblebees (Bombus vosnesenskii) reared in common-garden conditions.
Chill coma recovery time (CCRT) is an ecologically-relevant metric of cold tolerance that is correlated with geographic distributions of diverse insects. When exposed to low temperatures insects enter chill coma, a reversible state in which they are alive but unresponsive. The ability to quickly recover neuromuscular function after chill coma likely affects fitness, particularly in cold climates—insects in chill coma are incapable of feeding or reproducing and make easy prey. Bumblebees (genus *Bombus*) are broadly distributed in diverse climates where they may be regularly exposed to temperatures low enough to induce chill coma. Yet they are adept at regulating body temperature and workers (females) spend nights in temperature-regulated nests. In contrast, male bumblebees do not return to the nest after emerging and thus must contend with daily cold exposure. We therefore predicted that male bumblebees would recover more quickly from chill coma than females. We measured CCRT of male and female *Bombus vosnesenskii* collected from nests established from field-caught queens and reared under common garden conditions. We held bees in chill coma at -4 °C for 2 hours and then placed them at 22 °C and measured time elapsed before they displayed coordinated muscle movement. Contrary to our prediction, female bumblebees recovered from chill coma ~1 minute faster than did males. This difference was robust to differences in body mass and consistent across nests from queens collected from diverse geographic locations.

50.1 JAROMIN, E*; SADOWSKA, ET; KOTEJA, P; Jagiellonian University, Institute of Environmental Sciences, Poland; *ewa.jaromin@doctoral.uj.edu.pl*
Monoamine reuptake inhibitors alter exercise performance in bank voles selected for high swimming-induced aerobic metabolism
Exercise performance depends on both physiological abilities (*e.g.* muscle strength) and behavioral characteristics (*e.g.* motivation). We tested the hypothesis that evolution of increased aerobic exercise performance can be triggered by evolution of motivation to undertake physical activity. We used a unique model system: four lines of bank voles (*Myodes glareolus*) selected for high swimming-induced aerobic metabolism ("aerobic" A-lines). In generation 21, voles from the A-lines achieved 61% higher aerobic metabolism during swimming (VO_{2swim}) than voles from four unselected, "control" C-lines. Because the voles could vigorously swim or float on the water surface, the level of VO_{2swim} depended both on aerobic capacity and motivation to undertake intensive activity. The level of metabolism achieved during an exercise that depends mainly on aerobic capacity (forced running, VO_{2run}) was higher than VO_{2swim} in the C-lines (mass-adjusted LSM±SE [mlO_2/min]; run: 4.73±0.13, swim: 4.31±0.13; p=0.008), while the A-lines achieved similar VO_{2run} and VO_{2swim} (run: 6.09±0.13, swim: 6.31±0.13, p=0.13). Thus, we hypothesized that selection changed both aerobic capacity and neuronal mechanisms behind motivation to undertake activity. We investigated the influence of reuptake inhibitors of dopamine (vanoxerine), serotonin (fluoxetine) and noradrenaline (reboxetine) on VO_{2swim} and VO_{2run}. All drugs caused decreased VO_{2swim}, but VO_{2run} was decreased only by vanoxerine. The results indicate different neuronal processes underlying voluntary and forced activity. Because there were no differences in response to the drugs between A and C-lines, we are as yet unable to reach firm conclusions concerning the role of these monoamines in the evolution of increased aerobic exercise performance.

61.6 JAUMANN, S*; SNELL-ROOD, E; University of Minnesota; *jauma002@umn.edu*

Nutritional Stress Decreases Fecundity and Choosiness in a Butterfly

Nutritional stress can decrease fecundity, but it is unclear how such life history changes interact with behavioral strategies. On one hand, nutritionally stressed individuals may be more choosy to maximize the fitness of the few offspring they can afford to produce; on the other hand, these individuals may not have the resources to invest in costly choice behavior. Choosiness during oviposition exhibits a trade-off with fecundity in satiated butterflies, suggesting that choosiness is costly under normal conditions. We therefore hypothesized that poor nutrition in juvenile and/or adult environments could reduce choosiness in these insects. To test this hypothesis, we manipulated nutrition during the larval and adult stages of the butterfly *Pieris rapae*. Adult females were allowed to lay eggs in a host plant assay in which some plants had conspecific models previously found to deter egg-laying. Females from poor-nutrition adult treatments laid fewer eggs and were less choosy than individuals from high-nutrition adult treatments. There were no effects of larval nutrition. To better understand why we found no effect of larval nutrition, we surveyed the effects of variation in larval nutrition on a suite of life-history traits in a follow-up experiment. Taken together, our data suggest that nutritional stress can have major consequences- not only reproductive costs, but also impaired decision-making– potentially because egg production and information processing are both metabolically costly.

63.6 JAYARAM, K*; GOLDBERG, B; DOSHI, N; WOOD, R.J.; Harvard University; *kjayaram@seas.harvard.edu*

Towards rapid running at resonance using HAMR, a biologically-inspired robotic platform

Rapid and agile animal locomotion has inspired generations of rapid running legged robots. We present, the Harvard Ambulatory MicroRobot (HAMR) - an insect scale (45 mm long, 1.43 g) quadrapedal robot capable of high speed locomotion up to 50 cms^{-1} (>10 BLs^{-1}) on level ground, making it one of the smallest yet fastest terrestrial robots. HAMR has 8 actuators in total, 2 for each leg to independently control vertical and fore-aft motions. By commanding the phase between actuators, the robot can execute desired leg trajectories resulting in six gaits over a range of frequencies (0-60 Hz) without need for stride control. Few biological counterparts (mites and tiger beetles) exhibit such a broad range of stride frequencies. While higher actuation frequencies allow HAMR to run faster, they also excite the leg transmission resonances making foot trajectories highly susceptible to parasitic phase shifts from desired gaits, and therefore, not suitable for locomotion. Unpredictable ground contacts make rapid running further challenging. These observations led us to design new sensing mechanisms to estimate leg actuator positions and detect ground contact. Preliminary experiments with a single leg robot prototype predict atleast 3-fold increase in stride length while operating at higher stride frequencies suggesting a significant improvement in running performance. Such a locomotion strategy draws parallels with the American cockroach Periplaneta americana, which initially increases stride frequency to increase speed and subsequently stride lengths via gait change (hexapedal to quadrapedal to bipedal). With easily adjustable morphological features like tail or posture or additional legs, we believe that HAMR is a unique and powerful platform for testing locomotion hypotheses in biological systems at scale.

P3.186 JENNINGS, E.C.*; HENDERSHOT, J.M.; SHEMAS, S.; RIBEIRO, J.M.C.; WEIRAUCH, M.T.; BENOIT, J.B.; University of Cincinnati, National Institute of Allergy and Infectious Diseases, Cincinnati Children's Hospital Medical Center; *jenninec@mail.uc.edu*

RNA-seq analysis sheds light on the molecular mechanisms underlying pregnancy in the live-bearing cockroach, Diploptera punctata

Viviparous reproduction is characterized by maternal retention of developing offspring within her reproductive tract during gestation, culminating in live birth. In some cases a mother will provide nutrition beyond that present in the yolk; this is known as matrotrophic viviparity. While this phenomenon is best associated with mammals, it is observed in insects such as the viviparous cockroach, *Diploptera punctata*. Female *D. punctata* carry developing embryos in the brood sac, a reproductive organ that acts as both a uterus and placenta by protecting and providing a nutritive secretion to the intrauterine developing progeny. While the basic physiology of *D. punctata* pregnancy has been characterized, little is known about the molecular mechanisms underlying this phenomenon. This study combines RNA-seq analysis, RNA interference, and other assays to characterize molecular changes associated with *D. punctata* reproduction and provides the most complete gene set to date for this species. A comparison of four stages of the female reproductive cycle revealed unique gene expression profiles corresponding to each stage. Differentially regulated transcripts of interest include the previously identified family of milk proteins, transcripts associated with juvenile hormone metabolism, and other reproduction-associated transcripts. RNA interference experiments reveal potential impacts of juvenile hormone breakdown in maintaining pregnancy in *D. punctata*. Additional experiments explore the potential use of DNA methylation as an epigenetic mechanism in *D. punctata*.

P1.279 JENSEN, MM*; SALADRIGAS, AH; BENNETT, AE; GOLDBOGEN, JA; Stanford University, Santa Catalina School, Stanford University ; *mmjensen@stanford.edu*

Three-dimensional morphology and flow characteristics of baleen

Baleen whales are filter feeders, consuming aggregations of zooplankton from the water column using baleen plates inside the mouth. Baleen consists of keratin plates arranged in racks, which fray on the inside edge and create a dense fibrous mat. Baleen whales include some of the largest animals on the planet, which support themselves on vast numbers of small-bodied organisms by filter feeding. Despite the importance of baleen filtration to the natural history and ecology of these predators, very little is known about either three-dimensional baleen morphology or the mechanics of baleen filtration, including what role, if any, the fringe plays in filtration. To quantify the three-dimensional morphology of baleen plates, we used computed tomography (CT) to image partial baleen racks from five species. For each baleen specimen, we calculated the percentage by volume of both plate material and the complementary void between plates for seawater flow during filtration. By volume, baleen plates comprised 14-34% of the imaged racks. The sei whale specimen had the smallest plate and largest void volumes, while the gray whale specimen had the largest plate and smallest void volumes. The relationship between plate/void volume between species likely reflects the functional constraints associated with foraging on different prey items, as well as differences in filter feeding strategies. We also investigated whether the baleen fringe modulates flow through baleen plates using a gravity-driven water flume. Flow rates through partial racks of baleen from a blue whale, a humpback whale, and a fin whale were not significantly different than the flume's flow rate with no baleen, suggesting that neither the fringe mat nor the baleen plates produce significant hydrodynamic resistance during filter feeding.

73.3 JEW, C*; THOMSEN, M; BAYLEY, M; HICKS, J; university of California Irvine, Aarhus University; *cjjew@uci.edu*

The effects of aquatic hypercanpia on air-breathing fishes

The notion that bimodal breathers (animals that breathe both air and water) obtain O2 from the air and exhale CO2 into the water has been well established in the literature. However, while the majority of supporting experiments tested animals maintained in hypoxic water, the freshwater systems that bimodal breathers inhabit have been reported to be hypercapnic as well. Using a biomodal respirometer, data from three air-breathing species show that when in hypercapnic water, excretion of CO2 into the air signicantly increases and can account for 10% to 70% of metabolically produced CO2 across species. The large variation between species suggests the independent evolution of air-breathing organs and behaviors result in different CO2 respiratory patterns. However, all three species continued to rely on the water for CO2 excretion to some extent when submerged.

103.6 JIMÉNEZ PADILLA , Y; LACHANCE, M-A; SINCLAIR, BJ*; Western University, London, ON, Canada; *bsincla7@uwo.ca*

The gut yeast microbiota determines insect recovery from chill coma

Understanding the role of the microbiota in determining animals' physiological phenotypes remains a grand challenge in organismal biology. Although yeasts are a key component of the insect gut microbiota, the role of yeasts has often been overlooked in favor of the readily-sequenced bacteria. Here we describe an experimental system of *Drosophila melanogaster* and an associated gut yeast, *Lachancea kluyveri*. We show that colonization of the gut by yeast reduces chill-coma recovery time (an important proxy for thermal tolerance in insects), and that the yeast has to be alive to elicit this phenotype. There is some evidence that yeast colonization determines inter-individual variation in chill coma recovery time. Together, these results imply that variation in insect cold tolerance (and likely other aspects of physiology) may be driven, at least in part, by the gut microbiota.

111.6 JIMENEZ, A.G.*; DIAS, J; NGUYEN, T; REILLY, B; ANTHONY, N; Colgate University, University of Arkansas; *ajimenez@colgate.edu*

Effects of thermal hormetic priming on muscle oxidative stress and muscle structure in slow-growing and fast-growing Coturnix quail lines

Climate change models warn that mean global temperatures are increasing and heat events will become more common, thus, it is important to consider how animals will cope with increases in environmental temperatures. Whereas studies highlight dire consequences of increasing temperatures for animals, we examined whether developing in warmer temperatures via hormetic priming would physiologically benefit adult quail. We used two lines of quail *Coturnix coturnix japonica*, one selected for slow growth and another for fast growth, to examine changes in muscle oxidative stress and structure across four reciprocally-crossed temperature treatment groups. Slow-growing quail had significantly higher citrate synthase (CS) activity compared with fast-growing quail, and hormetically primed birds had lower CS activity. Peroxyl (OOH•) radical scavenging capacity differed between temperature treatment groups, while hydroxyl (OH•) radical scavenging capacity differed between growth lines. We found significant differences in lipid peroxidation (LPO) damage between temperature treatment groups, where quail that experienced no variation in temperature showed higher LPO, while birds that were hormetically primed showed lower LPO. Finally, muscle fiber diameter was larger in fast-growing quail compared with slow-growing quail, and hormetically primed birds that experienced an acute thermal challenge had larger muscle fibers, possibly indicating a metabolic cost savings related to increased thermal load. Hormetic priming in quail showed physiological benefits as less oxidative stress is accumulated and muscle fiber diameters increased. Additionally, fast-growing quail may produce more reactive species, but may also profit more from thermal hormesis.

P1.212 JIMENEZ, YE*; BRAINERD, EL; SUMMERS, AP; Brown University, University of Washington; *yordano_jimenez@brown.edu*

Comparative Biomechanics of the Defensive Dorsal Fin Spine in Filefishes and Triggerfishes

Many fishes use large, modified fin spines to defend against predators. The material and structural properties of the spine must be capable of withstanding the forces associated with predatory encounters, as failure to do so can be costly. In filefishes (Monacanthidae) and triggerfishes (Balistidae), the large dorsal fin spine is modified into a formidable defensive structure that can be held in an erect position by specialized locking mechanism. The spine can either 1) increase the fish's effective body depth to protect against gape-limited predators or 2) lock itself inside inaccessible crevices. In either case, the loads placed on the spine could cause it to bend or break. We use high-resolution CT scans of 19 species to describe morphological variation and quantify the mineralization and second moment of area of the spine. We found that triggerfish spines are completely solid, whereas filefish spines are hollow inside. Additionally, most filefishes had spines covered with small, laterally projecting spines, while triggerfish spines usually had small bristly spines at the tip. Both families had a second moment of area that starts high at the wide base and gradually decreases moving toward the tip. In filefishes, the presence of small spines produced substantial, intermittent rises in the second moment of area along length of the spine—producing an overall oscillating trend in the second moment of area not found in triggerfishes. Despite these differences in the second moment of area, mineralization was similar for all species—ranging from 40 to 60%. These data suggest that filefishes and triggerfishes modulate spine flexural stiffness primarily through changes in morphology, and not changes in the material composition of the spine.

S7.9 JOCKUSCH, E.L.; University of Connecticut; *elizabeth.jockusch@uconn.edu*

Developmental and Evolutionary Perspectives on the Origin and Diversification of Arthropod Appendages

Jointed appendages are the hallmark of arthropods, and diversification of these segmentally repeated structures has helped generate the diversity of arthropod body plans. The resolved phylogenetic context for arthropods, combined with a well characterized model of appendage development in *Drosophila*, provides a baseline for comparative studies of ventral appendage diversification. The evolution of distinct appendage identities along the anteroposterior axis (i.e., diversification of serial homologues) occurred early in arthropod history with highly divergent morphologies homologized via differential retention and loss of components of an ancestrally biramous appendage. Although still piecemeal, comparative data on gene expression and/or function are available for all four major clades of arthropods, as well as from a lobopodous outgroup, the Onychophora. These data provide insight into the developmental basis for appendage diversification at three distinct levels: across lineages, serial homologues and life stages. Examples from each are used to highlight more general patterns and open questions in the evolution of development. For example, preexisting patterning information, including that provided by core network components, has been repeatedly coopted to regulate later development of novel species-specific features. Most structural divergence across serial homologues has occurred via tinkering with their ancestrally shared developmental network, but phylogenetic homeosis has also occurred repeatedly. Furthermore, as might be predicted based on the combination of early evolutionary divergence but a shared genome, serial homologues show a complex mixture of independent and dependent developmental evolution within lineages.

P1.26 JOCQUE, HJ*; BUBAK, AN; SWALLOW, JG; JOCQUE, Harper; University of Colorado Denver; *harper.jocque@ucdenver.edu*

Serotonin, fluoxetine, and larval behavior in the stalk-eyed fly Teleopsis dalmanni

Serotonin is a monoamine neurotransmitter that is widely conserved across invertebrates and vertebrates. It is found primarily in the central and enteric nervous systems and mediates a variety of physiological, morphological, and behavioral traits including heart rate, locomotion, digestion, and social behavior. Pharmaceutical and pesticide contaminants in the environment may impact the monoaminergic systems of non-target organisms, including insects. Sublethal physiological, morphological or behavioral effects of monoamine disrupting contaminants may have fitness consequences for affected non-target organisms. Among the most common monoamine disrupting contaminants are selective serotonin reuptake inhibitors (SSRIs), including the mood disorder drug fluoxetine, which increase the serotonin available to bind to postsynaptic cells. To explore the sublethal impact of fluoxetine on insect serotonergic systems and behaviors, the stalk-eyed fly *Teleopsis dalmanni* were used. This study examined sublethal consequences of chronic fluoxetine exposure on *T. dalmanni* larvae behavior and gene expression. Larvae experienced chronic oral dosing of fluoxetine or received control food without the drug. Third instar larvae locomotion and phototaxis were quantified. Quantitative PCR was used to measure both serotonergic and developmental gene expression. Results will be discussed in the context of the chronic disruption to the serotonergic system and the presence of pharmaceuticals in the environment.

132.1 JOHANSEN, JL*; ESBAUGH, AJ; University of Texas Marine Science Institute; *jacob.johansen@utexas.edu*

Chronic impairment of cardiorespiratory function and swim performance of red drum (Sciaenops ocellatus) following acute exposure to naturally weathered crude oil

Acute exposure to crude oil can significantly impair swim performance and cardiorespiratory function of larval and juvenile fish; however, little is known about the capacity for recovery. Red drum is a commercially important apex predator native to the Gulf of Mexico which was directly exposed to the 2010 Deep Horizon oil spill. Here we examine recovery from exposure to naturally weathered oil-water accommodated fractions. We focused on swimming performance, aerobic scope (ASc), and the capacity to repay oxygen debt following exhaustive exercise (EPOC), which are critical for success of all life stages of fishes. Swimming performance and ASc determine the capacity to hunt prey and evade predators, while EPOC determine the capacity to rapidly repeat these activities. All performance measures were compromised after a 24h critical exposure causing a 10-13% reduction in swimming performance and 18% reduction in ASc. No signs of recovery were found up to six weeks' post-exposure.

95.6 JOHNSEN, S*; RUXTON, GD; Duke Univ., Univ. of St. Andrews; *sjohnsen@duke.edu*

Join Now! The increased visibility of large groups of aquatic and aerial organisms is far outweighed by the benefits of aggregation

Aggregation is a common life-history trait in many species. Qualitative understanding of how aggregation by prey influences their encounter rates with predators is critical for understanding predator-prey interactions and trophic webs. We extend a recently-developed theory on visibility to predict the consequences of grouping in terms of increased visual detection of groups by predators. Our model suggests that enhanced visibility is relatively modest, with maximum detection distance typically only doubling for a 100-fold increase in the number of prey in a group. This result suggests that although larger groups are more easily detected, this cost to aggregation will in many cases be dominated by benefits, especially through risk dilution in situations where predators cannot consume all members of a discovered group. This in turn helps to explain the ubiquity of grouping across a great variety of taxa. We also find that the visibility cost of grouping increases rapidly as illumination levels drop, with this increase occurring at greater light levels in aerial versus aquatic organisms. In the case of aerial organisms, the cost increases rapidly during twilight, suggesting that this is a less advantageous time to aggregate.

P1.5 JOHNSON, D*; STAHLSCHMIDT, ZR; Univ. of the Pacific; *zstahlschmidt@pacific.edu*

Backyard ANTology: Using citizen science to open an ecological black box in California's Central Valley

Citizen Science (CS) is a powerful tool that can promote education and conservation by facilitating the participation of non-scientists in research endeavors. Its implementation can lead to the advancement of ecological theory, and the number of peer-reviewed CS papers has increased nearly 800% in the last five years alone. Thus, we developed Backyard ANTology, a CS outreach program focused on the distributional patterns of ants in California's Central Valley. Ants are tractable focal taxa that play important roles in many ecosystems and exhibit variation in biodiversity across urban-rural gradients. Yet, there is a paucity of ecological information on ants in the Central Valley, a region characterized by a range of human-impacts—from rapid urbanization to intensive agriculture. Our program aims to open this ecological black box while also engaging citizens in science they can conduct in their schools, parks, or backyards. Participants request ant collecting kits through a web interface (www.backyardantology.weebly.com), collect ants wherever they choose, fill out information cards, and return their collected ants via pre-paid envelopes. We identify the ants and post results on our website, which also contains general information about frequently encountered ant species of the Central Valley. Thus, the website is designed to inform participants and non-participants, with the ultimate goals of promoting knowledge and recruiting more participants. To date, participants ranging from 3-71 years of age have collected 13 ant species, largely outdoors and in residential areas. Ongoing research is also assessing how participation in Backyard ANTology changes participants' attitudes toward science, and future efforts aim to integrate a K-8 learning module that meets the state of California's educational standards.

P3.242 JOHNSON, K.; MCCLINTON, J.; JENNINGS, D.H.*; Southern Illinois University - Edwardsville; *dajenni@siue.edu*

Immunohistochemical Analysis of Jaw and Buccal Pumping Muscle Development and Metamorphosis in Tadpoles with Different Feeding Strategies.

Most amphibians have two distinct periods of development; embryogenesis which results in the formation of the larval stage, and metamorphosis which transforms the larva into an adult. The most dramatic metamorphic transformations occur in frogs where virtually every tissue is remodeled. The current work uses myosin antibodies and whole-mount immunohistochemistry to describe jaw and buccal pump muscle development and metamorphosis in tadpoles of Eastern Narrowmouth Toads (*Gastrophryne carolinensis*), American Toads (*Anaxyrus americanus*), and Gray Treefrogs (*Hyla versicolor/chrysoscelis*). Narrowmouth Toads differ from the other species in having a more anterior origin of the levator mandibulae muscles from the palatoquadrate, reduced size and dorsal-most margin of the orbitohyoideus, and increased size and more oblique fiber orientation of the interhyoideus. Similar differences have been reported in previous work comparing microhylid tadpoles with members of other frog families. Architectural changes in the orbitohyoideus and interhyoideus in Narrowmouth toads are associated with filter feeding of small-suspended particles as opposed to an ancestral generalized feeding strategy based on scraping food from the substrate using keratinized mouthparts. Ontogenetic changes in muscle fiber angles between the orbitohyoideus and the levator mandibulae, and the ratio between the interhyoideus and orbitohyoideus also differ among feeding strategies. Our descriptions of jaw muscle development in *G. carolinensis* are consistent with decreased developmental rate and early offset of jaw development as has been hypothesized for closely related frogs with similar feeding strategies.

69.5 JOHNSON, AB*; FOGEL, NS; LAMBERT, JD; University of Rochester; *adamjohnson@rochester.edu*

How the Mollusk Shell Margin controls Shell Shape

Many mollusks have external, calcified shells that protect against biotic and abiotic stresses. Shells are fantastically varied in shape, size, ornamentation, and pigmentation in response to these ecological pressures. Despite this incredible diversity in shell morphology, the cellular and developmental mechanisms underlying shell growth are poorly understood. Growth and shell shape are controlled by the shell margin, a band of cells surrounding the shell opening. Here, we characterize and define *Ilyanassa obsoleta's* shell margin into functional zones, each with distinctive cell morphology, function, and gene expression. Within these zones, we have discovered two zones of proliferation, as judged by EdU cell proliferation experiments. Within the first, most anterior growth zone, we find that cell divisions are strongly biased to be transverse relative to the anterior-posterior axis; this pattern of division can explain the observed circumferential expansion of the shell aperture. These divisions are left biased which is consistent with the observed higher rate of aperture expansion on the left side. In the second, more posterior growth zone, we find that cell divisions are significantly biased so they occur at an oblique angle to the right of the anterior-posterior axis. This can explain the greater aperture extension on the right side of the margin, which generates the coil of right-handed shells like *Ilyanassa*. These experiments describe how cellular behaviors can generate the growth patterns of gastropod shells.

P3.263 JOHNSON, AS*; ELLERS , O; QU, X; DICKINSON, ES; HARMON, K; ARMIYAW, A; DICKINSON, P; Bowdoin College; *ajohnson@bowdoin.edu*

The role of feedback from physiologically relevant stretches in controlling heart contraction in the American lobster, Homarus americanus

The neurogenic heartbeat of crustaceans is controlled by a 9-neuron pattern generator, the cardiac ganglion (CG), which includes 5 motor neurons and 4 premotor neurons; these neurons are electrically and chemically coupled, so that they fire nearly synchronous driver potentials and bursts of action potentials. Dendritic processes of both motor and premotor neurons appear to provide direct stretch feedback to the CG. We characterized (1) natural stretches of the lobster heart *in vivo* and (2) responses of CG neurons to stretch in semi-isolated preparations that included the CG and the transverse muscle fibers that underlie the premotor neurons. *In vivo* we characterized natural deformations of the ventral heart surface at 3 locations and directions during ongoing heart contractions: anterior transverse, posterior transverse and longitudinal. Movements were determined from videos in which the ventral side of the lobster was removed to reveal the pericardial cavity, but supporting ligaments and arteries that suspend the heart remained intact. Strains along the posterior transverse direction were greater than those along either the anterior transverse or the longitudinal direction. Interestingly, the premotor neurons, richly associated with stretch-sensitive dendrites, are located in the posterior region. In isolated CG-muscle preparations, stretch over multiple heartbeats elicited increased frequency and decreased duration of driver potentials; these changes were highly dependent on force. Stretch also elicited an initial phase delay in the driver potentials, which was dependent not only on force but also on strain rate. NSF IOS-1353023, NIH 8P20GM103423-12, Doherty Fdn/Bowdoin College.

92.1 JOHNSON, MA*; IVANOV, BM; KIRCHER, BK; Trinity University, San Antonio, Texas, University of Florida, Gainesville; *mjohnso9@trinity.edu*

Structure Size, Not Behavioral Use, is Associated with the Evolution of Muscle Fiber Size in Anole Lizards

Muscular contractions underlie all animal movements, and larger muscles generally allow the generation of greater force and/or more frequent behavioral use. Yet, studying the evolution of muscle fiber size is confounded in many taxa by "training effects," in which muscle fibers increase in size as the result of their use. Here, we examined 30 species of Caribbean *Anolis* lizards, as previous research has shown that these lizards have relatively low plasticity in response to training, and so variation in muscle size should largely reflect heritable differences among species. To determine whether muscle fiber size evolves in association with the size of a structure moved by muscular contraction or the rate and duration of its contraction, we studied two behavioral systems: movement and size of the dewlap, a throat fan used in aggressive and courtship displays and moved by the ceratohyoid (CH) muscles; and movement and size of the hemipenes, paired copulatory organs moved by the retractor penis magnus (RPM) muscles. We performed behavioral observations of each species in the field, and collected muscle samples for histological measurements. Our results showed that after controlling for body size, CH fiber size was not associated with dewlap display frequency or duration, but was larger in species with larger dewlaps. Likewise, RPM fiber size was not associated with frequency of copulation, but was larger in species with larger hemipenes. These data support the hypothesis that in anoles, muscle fiber size evolves as a function of the size of the structure moved by the muscle, and not the behavioral use of that muscle.

P1.81 JOHNSON, M*; LOUBRIEL GRAJALES, D; NIEDZIALEK, O; PEREZ TORRES, M; MELENDEZ, A; ALEMÁN RÍOS , J; MOSIER, A; ABRAMSON, C; GIRAY, T; BARTHELL, J; GONZALEZ, VH; AGOSTO RIVERA, J; Dickinson College, University of Puerto Rico at Rio Piedras, Bard College, OKLAHOMA STATE UNIVERISTY, Oklahoma State University, University of Central Oklahoma, University of Kansas; *johnsome@dickinson.edu*

A comparative analysis of the circadian rhythms of specialist and generalist bees visiting Convolvulaceae flowers

Circadian rhythm is an internal biological clock that controls nearly every aspect of life for all living things. Circadian rhythm has been previously studied in organisms ranging from *Apis mellifera* to humans; however, this was the first study to analyze the rhythms of both *Systropha curvicornis* and *Systropha planidens*. Both *Systropha* species were found together for the first time in Turkey, which indicates that geography is a strong component in the distribution of the species. A combination of over 120 *S. curvicornis*, *S. planidens*, and generalist, non-*Apis mellifera* bees were collected and placed into four TriKinetics activity monitoring system monitors. Meanwhile, the relationship between *Systropha* and *Convolvulus* flowers is studied to understand the circadian rhythm of *Systropha*. This is consistent with the idea that bees synchronize with the flowers that they forage at. Our finding that no *S. planidens* exhibited movement throughout the study, while a considerable fraction of *S. curvicornis* exhibited movement, may suggest a difference in foraging behavior. The three movement categories found in *S. curvicornis* indicate large variation of activity patterns in the population. If this variation is related to function or is random is unknown. Although there is variation in the activity pattern among the generalist population, their phase of movement is generally similar between each other and to the *Systropha curvicornis*. These findings have implications in adding to the knowledge of the circadian rhythms of specialists bees and also their behaviors.

P2.129 JONES, JA*; BOERSMA, J; ENBODY, E; KARUBIAN, J; Tulane University, Washington State University; *johnajones91@gmail.com*

Ecological Determinants of Phenotypic Divergence in Female Coloration of Papuan Fairywrens

Birds exhibit a tremendous range of diversity in plumage color that spans the visual spectrum and is likely unmatched by any extant taxa group. Among closely related species that occur sympatrically, phenotypic variation in coloration is predicted to be relatively distinct, either because of sexual selection or in response to ecological factors, such as predation risk, sensory bias, hybridization avoidance, and interspecific aggression. Yet, when in allopatry, variation in sexual selection or ecological factors may drive further phenotypic distinction between sister taxa. These color signals may act in social interactions and have implications for both natural and sexual selection. Australo-Papuan fairywrens (Maluridae: Malurus) exhibit substantial diversity in plumage coloration and are a model system in studying sexual selection. Our research focuses on the degree to which ecological factors (here, social and habitat structure) may influence the expression of ornamented phenotypes in the white-shouldered fairywren (M. alboscapulatus). This species is notable because males are qualitatively similar in appearance across populations, whereas variation in coloration is found in females; female coloration ranges from drab to ornamented. We studied two populations of fairywrens in Papua New Guinea, representing either drab or ornamented female plumage. We used behavioral observations of color-banded individuals from both populations in combination with spatial analysis to explore how both sexes within the social pair use available habitat. Our findings are consistent with the idea that ornamentation is correlated with differences in habitat use and movement, and we discuss potential implications for the evolution of female ornamentation.

P3.207 JONES, A.J*; ORR, K.O.; ZUELOW, A.N.; BOURDEAU, P.E.; Humboldt State University; *ajj177@humboldt.edu*

Seasonal and Spatial Variation in Aboral Ossicle Density and Body Shape in Pisaster ochraceus.

Wave-protected and wave-exposed forms of the intertidal seastar *Pisaster ochraceus* have formerly been described as separate subspecies owing to differences in aboral ossicle density and pattern. However, a recent study of *Pisaster* populations in British Columbia suggests that these differences may be due to phenotypically plastic changes in body shape through the uptake or discharge of seawater. That study observed a positive relationship between ossicle density and wave-induced changes in star aspect ratio: aboral ossicle density tended to increase with increasing aspect ratio (an adaptive plastic response to increased flow conditions) as would be expected if sea star shape is achieved through deflation. Here, we examined whether the density and pattern of aboral ossicles in Northern California populations of *Pisaster* were correlated with spatial and seasonal variation in wave exposure in a manner consistent with flow-induced plasticity. We found that aboral ossicle density was significantly higher in stars at wave-exposed sites and during storm season when wave force is maximal; consistent with previous findings. However, we also found that variation in ossicle density was decoupled from variation in arm aspect ratio, which is inconsistent with previous findings. Current laboratory studies are being conducted to determine whether changes in aboral ossicle density represent phenotypically plastic changes in star body shape via the uptake or discharge of seawater in response to short-term variation in flow conditions.

127.3 JONES, BC*; SCHOECH, SJ; Univ. of Memphis; *jonesbc@gmail.com*

High Stress-Response Florida Scrub-Jays (Aphelocoma coerulescens) Are More Sensitive to Human Gaze.

Proactive and reactive coping styles describe the relationships among behavioral phenotypes (e.g., personality) and stress physiology, as well as consistent individual differences in cognition. Proactive individuals are hypothesized to be less sensitive to environmental cues and have relatively low hypothalamic-pituitary-adrenal (HPA) axis responsiveness to a stressor. In contrast, reactive individuals are more likely to detect and respond to subtle changes in the environment and respond to acute stressors with higher HPA axis activity. We explored the possible link between HPA axis responsiveness and the ability of free-living Florida scrub-jays (*Aphelocoma coerulescens*) to detect directional human gaze, a cognitive task. We tested whether scrub-jays exhibited consistent within-individual ability to detect human gaze by taking multiple measures of their willingness to approach a favorite food, peanuts, near a human that was facing toward or away from subjects. We also tested the ability of scrub-jays to detect subtle changes in a human's gaze by measuring their willingness to approach peanuts near a human that gazed directly at or tangentially to subjects. Further, we compared the ability to detect directional gaze with levels of HPA axis responsiveness by measuring levels of corticosterone (the primary avian glucocorticoid) in response to a standardized stressor. Scrub-jays exhibited consistent within-individual ability to detect human gaze. Additionally, scrub-jays that responded to a standardized stressor with relatively high levels of corticosterone exhibited a higher degree of discrimination between the direct and tangential gaze of a human. These results support the hypothesis that high stress-response individuals are more sensitive to their environment, and further suggest that measures of cognitive ability may be influenced by cognitive style (i.e., how an individual focuses its attention).

P3.190 JOSEFSON, CC*; HOOD, WR; Auburn University; *ccj0011@auburn.edu*

Using phenotypic variation in the lab mouse to deduce physiological variables that correlate with life-history variation

Artificial selection has been used to increase the expression of desirable traits in the lab mouse. Associated with this procedure, hundreds of well-characterized phenotypic variants (strains) are now available for use in research. Although these strains are typically used in biomedical research models, we propose that data from lab mice can be used to identify pleiotropic traits that contribute to life-history variation. We used the publicly available Mouse Phenome Database by the Jackson Laboratory to investigate correlations among life-history traits and between life-history and physiological variables in adult female mice. We used fitness-related variables in a principal component analysis, which resulted in two principal components (breeding frequency and reproductive performance) that describe the variance in reproductive traits. Scores from this analysis were then regressed against life-history associated traits (body mass, body composition, lifespan, and allocation to self-maintenance) and physiological variables (metabolism, mean serum IGF-1) in non-reproductive adult females. Interestingly, we found that lifespan did not significantly correlate with individual fitness-related variables (total number of offspring, litter size, or litters per dam), but did have a significant negative correlation with interval between consecutive litters. Further, we found that reproductive performance and longevity were not significantly correlated, as we had initially hypothesized. Our analysis of physiological variables supports the hypothesis that IGF-1 may contribute to variation in reproductive performance. Together, these results help understand what drives individual variation in life-history, as well as the phenotypic and physiological correlates that accompany this variation.

37.1 JOSEPH, P/N*; SASSON, D/A; EMBERTS, Z; MILLER, C/W; University of Florida; *pjoseph14@ufl.edu*

Making the Best of a Bad Situation: Males that Lose a Morphological Weapon Grow Larger Testes

Male sexually-selected weapons are often useful in achieving mating opportunities, via success in male-male competitive contests. For this reason, the loss of a weapon should decrease male mate acquisition. Yet some species possess weapons that can be autotomized, without regeneration, to escape immediate danger. We address whether and to what extent the loss of a weapon during development affects another important trait, the testes. Theory suggests that a trade-off between weapons and testes should exist. For this reason, males that have autotomized weapons during development should invest more in testes, but this hypothesis remains untested. We tested this hypothesis using the leaf-footed cactus bug, *Narnia femorata*, which naturally can drop its hind limb weapons. We measured testes mass for males that dropped a hind limb during development relative to three control treatments. Males that dropped a hind limb grew significantly larger testes than the control treatments. We found that females paired with males with larger testes produced more eggs, suggesting that such investment may enhance male fitness. Our results are the first to show that males may naturally compensate for losing a weapon by investing more in a post-copulatory sexually-selected organ and that this compensation is likely to lead to more productive matings.

103.1 JOST, JA; Bradley University; *jjost@fsmail.bradley.edu*

AMPK Activity Increases in Response to Acute Cold Stress in the Zebra Mussel

Ectothermic species are affected by environmental fluctuations, and studies are needed on thermal tolerances since changes in ambient temperature affect metabolic demands. Zebra mussels are highly invasive, yet little is known about their physiology under biologically relevant conditions, especially with regard to cellular parameters. This study utilized AMP-activated protein kinase (AMPK), a key regulator of cellular energy levels, to examine the effects of cold water temperatures on zebra mussel (*Dreissena polymorpha*) physiology. AMPK activity reflects changes in energy supply and demand, which are typically associated with high temperature stress. However, a previous study showed that cold acclimation resulted in a temporary elevation in AMPK activity in zebra mussels. In order to investigate this response further, zebra mussels were collected, exposed to a rapid and progressive temperature decrease to 10°C, and held at 10°C for 24 hours. AMPK activity did not increase above baseline levels during the progressive temperature decrease. However, by 24hrs, there was a significant elevation in AMPK activity. One possible explanation is that the processes associated with acclimation to cooler waters may be energetically taxing. In other species, the process of thermal acclimation involves changes in biochemical reaction rates and gene expression. Therefore, it is reasonable to assume that this process would temporarily increase metabolic demands. Zebra mussels are capable of thermal acclimation, and as ambient water temperature varies, the sublethal and lethal temperature ranges also vary. In addition, a two-week lab acclimation to winter conditions is sufficient to alter the thermal tolerances of summer collected mussels, suggesting that thermal acclimation can occur quickly and that water temperature is the main driver of this process.

123.7 JUNG, S*; CHANG, B; CROSON, M; STRAKER, L; GART, S; DOVE, C; GERWIN, J; Virginia Tech, Smithsonian Institution, North Carolina Museum of Natural Sciences; *sunnyjsh@vt.edu*

How seabirds (Morus bassanus and Sula leucogaster) plunge-dive without injuries

In nature, several seabirds (e.g. Gannets and Boobies) dive into water at up to 24 m/s as a hunting mechanism; furthermore, Gannets and Boobies have a slender neck, which is potentially the weakest part of the body under compression during high-speed impact. In this talk, we investigate the stability of the bird's neck during plunge-diving by understanding the interaction between the fluid forces acting on the head and the flexibility of the neck. First, we use a salvaged bird to identify plunge-diving phases. Anatomical features of the skull and neck were acquired to quantify the effect of beak geometry and neck musculature on the stability during a plunge-dive. Secondly, physical experiments of an elastic beam as a model for the neck attached to a skull-like cone revealed the limits for the stability of the neck during the bird's dive as a function of impact velocity and geometric factors. We find that the neck length, neck muscles, and diving speed of the bird predominantly reduce the likelihood of injury during the plunge-dive. Finally, we use our results to discuss maximum diving speeds for humans to avoid injury.

94.5 JUNG, SH; BECK, J; BHANDAWAT, V*; BHANDAWAT, vikas; Duke University; *vb37@duke.edu*

Independently Controlled Locomotor Primitives underlie Behavioral Response to Odors.

A cornerstone of ethology is that behavior comes in discrete packets, i.e., behavior can be temporally segmented into natural units. In some behaviors, these discrete packets are readily recognizable. But, in most behaviors, there is enough variability in these discrete packets to make them unrecognizable without the help of sophisticated analytical tools. Here we deploy a powerful analytical tool to extract these discrete packets in the context of a *Drosophila's* locomotor response to odors. We reasoned that in the case of a fly's locomotion, as in other complex behaviors, stimuli do not act directly on the observables (such as speed and turn rate) that define locomotion but on a higher-level strategy, which in turn affect the observables. This scheme can be mathematically described by a Hierarchical Hidden Markov Model (HHMM). We show that a two-layered HHMM in which there are 6-high level states or discrete packets or "locomotor primitives" is an intuitive model for a fly's locomotion. We also demonstrate that odors modulate locomotion by altering the time a fly spends in the 6 high-level states. Finally, we extract the relationship between neural response and behavioral response elicited by food odors. We show that most food odors activate 7 olfactory receptor neuron (ORN) classes. Using genetic mutants and optogenetics, we were able to activate precise subsets of these 7 ORN classes. We found a modular organization in which each ORN class affects the time a fly spends in a subset of locomotor primitives. In sum, in this study, we introduce HHMM as a powerful method to extract the natural units of behavior and use this method to unravel the neural underpinnings of a behavior that is critical to a fly's ecology.

P3.85 JUNG, J*; MCDANIEL, JG; WARKENTIN, KW; Boston University; *jungj@bu.edu*

Ontogeny of Vibration-cued Escape-hatching in Red-eyed Treefrogs: Two Reasons Older Embryos Hatch More

Arboreal embryos of *Agalychnis callidryas* hatch up to 30% prematurely to escape from egg predators, cued by vibrations in attacks. Embryos modulate hatching based on multiple, non-redundant frequency and temporal properties of vibrations, reducing the chance of false alarms that unnecessarily expose hatchlings to increased risk in the water. We used vibration playbacks to test two hypotheses about why hatching responses increase developmentally. First, sensory development might improve cue detection. We constructed amplitude-response curves across stages, using a synthetic stimulus designed to elicit strong hatching responses. We found that the response threshold for hatching decreases substantially with development, consistent with a sensory constraint on cue detection acting soon after the onset of vibration-cued hatching responses. Second, because the cost of false alarms decreases developmentally, but missed cues are still deadly, more developed embryos may accept more false alarms to avoid the risk of sampling ambiguous vibrations. We designed three rhythmic stimuli with predator-like vibration frequencies that varied in duration: interval pattern, and thus information delivery rate. One had a pattern known to elicit high hatching; the others had slower and faster patterns that both elicited little hatching at the first stage tested. As embryos approached spontaneous hatching, their responses to the slow and fast patterns diverged as predicted from their different sampling costs and the changing missed cue-false alarm trade-off. Thus, both developmental constraints on sensory ability and optimal embryo responses to ambiguous information appear to affect developmental changes in embryo behavior at different stages during the plastic hatching period.

120.3 JURCAK, AM*; MOORE, ME; MOORE, PA; Bowling Green State University , Baldwin Wallace University; *ajurcak@bgsu.edu*

Understanding the sensitivity of native and invasive prey to the impact space of a predator.

Non-consumptive effects (NCEs) of predators can influence prey as much or more as consumptive effects (CEs). NCEs are mediated through the prey's knowledge of a predator's presence via sensory signals. The purpose of this study was to investigate a predator odor dose-response curve for different prey species (two native and one invasive crayfish). We used a controlled flow-through model stream to deliver odor to test subjects. In addition, the chemical concentration within the test arena was quantified using an electrochemical sensor system. Bass were chosen as the donor for the predatory odor. Crayfish were placed in the arena with a predator odor source and allowed to move throughout the arena as well as interact with resources. The movement pattern and different behaviors of prey (crayfish) were digitized for the entire 15 minute period. Anti-predator behavior exhibited by the prey were both concentration and prey species dependent. This work demonstrates that models of non-consumptive effects need to include differences in prey sensitivity across different species.

63.4 JUSUFI, A*; VOGT, DM; WOOD, RJ; LAUDER, GV; HARVARD; *ardian@seas.harvard.edu*

Undulatory Swimming Performance and Body Stiffness Modulation in a Soft Robotic Fish

Undulatory motion of the body is the dominant mode of locomotion in fishes, and numerous studies of body kinematics and muscle activity patterns have provided insights into the mechanics of swimming. However, it has not been possible to investigate how key parameters such as the extent of bilateral muscle activation affect propulsive performance due to the inability to manipulate muscle activation in live, freely-swimming fishes. We manufacture and utilize a set of actively-controlled pneumatic actuators attached to a flexible foil to gain insight into undulatory locomotion and mechanisms for body stiffness control. Two soft actuators were attached on each side of a flexible panel with stiffness comparable to that of a fish body. To study how bilateral contraction can be used to modify axial body stiffness during swimming, we ran a parameter sweep of actuator contraction phasing and frequency (Jusufi, Vogt, Wood, Lauder, 2016). Thrust production by the soft pneumatic actuators was tested at cyclic undulation frequencies ranging from 0.3Hz to 1.2Hz in a recirculating flow tank at flow speeds up to 28cm/s. Overall, this system generated more thrust at higher tail beat frequencies, with a plateau in thrust above 0.8Hz. Self-propelled speed was found to be 0.8 foil lengths per second or circa 13cm/s when actuated at 0.55Hz. We find this active pneumatic model is capable of producing substantial trailing edge amplitudes with a maximum excursion equivalent to 1.4 foil lengths, and of generating considerable thrust. Altering the extent of bilateral co-contraction in a range from 17% to -22% of the cycle period showed that thrust was maximized with some amount of simultaneous bilateral co-contraction of approximately 3% to 6% of the cycle period ($p<0.05$). This experimental platform provides a new physical model for studying aquatic propulsion with active control of undulatory kinematics. Body-caudal shape changes facilitated by soft actuators could enhance maneuverability in burst-type responses.

P2.177 JUTFELT, F; SUNDIN, J*; RABY, GD; KRåNG, AS; CLARK, TD; Norwegian Univ. of Science and Technology, Trondheim, Uppsala Univ., Uppsala, Univ. of Windsor, Windsor, Univ. of Gothenburg, Fiskebäckskil, Univ. of Tasmania & CSIRO Agriculture and Food, Hobart; *josefin.sundin@neuro.uu.se*

Two-Current Choice Flumes for Testing Avoidance and Preference in Aquatic Animals

Aquatic chemical ecology is an important and growing research field that involves understanding how organisms perceive and respond to chemical cues in their environment. Research assessing the preference or avoidance of a water source containing specific chemical cues has increased in popularity in recent years, and a variety of methods have been described in the scientific literature. However, there is a clear absence of standardised methodologies, which makes comparisons across studies difficult. Some methodological problems occurring in the literature include turbulent flows causing mixing of cues, inappropriate size of choice arenas for the animals, short experiments with stressed animals, failure to report how observation- and researcher-biases were eliminated, general underreporting of methodological details, and underutilisation of collected data. We propose best-practice guidelines on how to build, test and use two-current choice flumes to measure the behavioural responses of aquatic animals to chemical cues. The guidelines include steps that can be taken to avoid problems commonly encountered when using two-current choice flumes. Our aim is to provide a set of standards that will ensure data quality, transparency, and replicability in future studies in this field.

P1.275 KABIR, R; AVERY, N; SHAIK, M*; HALL, M; BERG, O; MüLLER, U; California State University, Fresno; *rrkabir8@mail.fresnostate.edu*

Prey Size Selectivity in Utricularia vulgaris

Bladderwort are a genus of carnivorous plants that traps zooplankton of submillimeter size by active suction. They are among the smallest suction feeders, with gapes ranging from 0.18 to 1.2 mm in the species *Utriculria vulgaris*. Other suction feeders of similar size (larval fish) are relatively ineffective feeders, in contrast to adult fish. Both larval and adult fish capture predominantly prey that is considerably smaller than their gape; prey size and prey size range increase with increasing gape size. In fish larvae, the feeding apparatus grows positively allometrically; in adult fish, feeding apparatus and gape scale isometrically with body size. The aim of this study is to explore the size selectivity and feeding morphology of bladderwort. We found that the traps of *U. vulgaris* range over one order of magnitude from 0.3 to 3 mm and with gape scaling roughly isometrically with trap size (scaling coefficient 0.95). To explore prey size selectivity, we conducted laboratory feeding trials with ostracods (size range 0.07 to 0.86 mm). We found that larger traps catch larger and a wider size range of prey, consistent with findings in fish. However in bladderwort, prey size distribution is biased towards large prey. Capture rates (number of prey caught within a given time period) as a measure of capture effectiveness is considerably lower in bladderwort (up to 5/day) than fish, including first-feeding fish (more than 5/hour), reflecting that plants capture prey for nutrients, not for energy.

P3.224 KACZMAREK, EB*; SUMMERS, AP; MOSER, ML; University of Miami, University of Washington, Friday Harbor Laboratories, National Marine Fisheries Service, NOAA; *elskabette@gmail.com*

Burying Behavior in Pacific Lamprey Ammocoetes

Many fishes have evolved the ability to bury into sandy substrates. To bury themselves, fish must displace a volume of sand equal to the volume of their entire body. An animal's burying ability depends on several factors, including body size, sand grain size, and sand density. The complex material properties of granular media make it difficult to mathematically model burial performance, so we need a breadth of empirical studies before we can move to models. We used larval Pacific lamprey, *Entosphenus tridentatus*, to experimentally explore how burial performance scales with body size. We observed that Pacific lamprey bury with a similar mechanism to that of sand lances (*Ammodytes*), and larval sea lamprey (*Petromyzon marinus* L.). That is, they begin burying by undulating rapidly to drive the head and about 1/3 of the body into the sand. Next, with their tails flat against the sand surface, they undulate the anterior portion of their bodies through the sand to drag their caudal regions completely under the substrate. To quantify the effect of body size on performance, we used high-speed video to record burial events of 12 lamprey (range: 8 to 63 mm in TL) and measured time spent burying. Total time to bury decreased with body length to the power of -1.393. This agrees with Quintella et al. (2007), who showed that in sea lamprey, larger animals buried faster.

109.1 KAGEMANN, C*; BRIGHT, L; GOUT, J; DOAK, T; KALTZ, O; LYNCH, M; Indiana University, Bloomington, IN, Institut des Sciences de l'Evolution, Montpellier, France ; *ckageman@indiana.edu*
Gene expression changes during infection of Paramecium caudatum by Holospora undulata bacteria.
Holospora is a genus of bacterial parasites that only grow and divide within one of the two nuclei of their *Paramecium caudatum* hosts. Our study focuses on *Holospora undulata*, a species that infects the micronucleus of specific *P. caudatum* strains. Infection comes at a significant growth-rate cost to the *P. caudatum* host, and we expect that host defense mechanisms are activated in response to the presence of *H. undulata*. Currently we are focused on determining what genes are associated with membrane trafficking and what stages of infection the resistant strains of *P. caudatum* are blocked at. To find the genes that are upregulated at specific time points during infection, we have been staging infections and isolating mRNA through the infection cycle. Preliminary results showed that after 30 minutes of non-resistant *P. caudatum* infection by *H. undulata*, approximately 106 genes were upregulated and 28 genes downregulated. Considering 9000 out of 18000 *P. caudatum* genes have a functional annotation, the small amount of functionally annotated genes from our experiments suggests that the genes that are being up and downregulated during *H. undulata* infection are *Paramecium*-specific genes and evolving quickly in response to the presence of *H. undulata*. From our preliminary results, some genes of interest include a MATE pathogen toxin efflux family protein and the homolog of *Paramecium tetraurelia* 51A surface antigen protein, both upregulated after 10 minutes of infection. Our research will provide insight into host-pathogen relationships in general, particularly in the *Rickettsial* family, *Holospora's* closest relative and also an intracellular parasite.

P3.171 KAHN, PC*; CAO, D; BURNS, M; BOYER, SL; Macalester College, San Diego State University; *pkahn@macalester.edu*
Nuptial gifts in the leiobunine harvestman (Opiliones, Sclerosomatidae): Nourishing treat or sensory trap?
Nuptial gifts are material donations given before or during copulation from male to female; gifts exist predominantly in the form of prey or other food items, or secretions from male glands. The "Candymaker" hypothesis as described by Warwick in 1999 states that males may include phagostimulants to work as sensory traps in their glandular nuptial gift offerings in order to exploit the female's gustatory response and gain a fitness advantage that may conflict with the female's reproductive interests. Despite their description in multiple suborders, the nuptial gift secretions of harvestmen (Opiliones) have never been analyzed for chemical content. In this study, samples from five different species (*L. ventricosum, L. politum, L. vittatum, L. calcar*, and *L. aldrichi*) representing the major *Leiobunum* lineages will be compared. Both mating behavior and male genital morphology vary between the species in this group, making this an intriguing system for comparisons across taxa. Specimens were collected at the Katharine Ordway Field Station in Inver Grove Heights, MN; with additional material loaned by the Minnesota Insect Collection. Nuptial gift issued from the penile alae and accessory glands was extracted and free amino acid profiles were compared to an amino acid standard using high-performance liquid chromatography (HPLC). Preliminary data suggest that harvestmen nuptial secretions contain free amino acids that could act as phagostimulants. This study contributes to the knowledge of harvestmen, an under-studied group of animals, as well as to our understanding of the biological role, constitutional variety, and chemical ecology of nuptial gifts.

P2.69 KAHN, AS*; LEYS, SP; Univ. of Alberta; *kahn@ualberta.ca*
Spicule and flagellated chamber formation in a growth zone of Aphrocallistes vastus
Three species of glass sponges (Class Hexactinellida) form massive deep water reefs by growing on the skeletons of past generations with new growth largely vertical, away from sediment that buries the lower portions. Growth is therefore essential for reef health, but how glass sponges produce new skeleton or tissue is not known. We used fluorescence, light, and electron microscopy to study skeletal and tissue growth in the reef-forming glass sponge *Aphrocallistes vastus*. The sponge consists of a single large tube (the osculum), usually with several side branches, each of which can function as an effective excurrent vent. New tissue forms at the tips of each of these extensions but how this occurs in a syncytial animal, and how the tubes expand laterally as the sponge gets larger, are both unknown. The fluorescent dye PDMPO labeled more spicule types in the tips of the sponge than elsewhere, indicating growth that was concentrated at the edge of the osculum. New tissue production was tracked using the thymidine analog EdU. EdU-labelled nuclei were found predominantly at the edge or 'lip' of the sponge oscula. In that region new flagellated chambers were formed from clusters of choanoblasts that spread out around the enlarging chamber. In cellular sponges clusters of choanocytes form flagellated chambers through several rounds of mitotic divisions to expand the chamber to full size. In contrast, chambers in glass sponges expand as choanoblasts produce enucleate collar bodies to fill them out. Growing chambers with enucleate structures may be an adaptation to life in the deep sea if chambers with cells, and therefore more nuclei, are costly to build.

47.4 KAHN, AS*; LEYS, SP; Univ. of Alberta; *kahn@ualberta.ca*
Energetics and the evolution of the glass sponge electrical coordination system
Glass sponges (Class Hexactinellida) are one of the most abundant filter feeders in the deep ocean. We present our hypothesis that their syncytial body construction arose to cope with the food-poor conditions in the deep sea. We also propose that once syncytial tissue arose in the glass sponge a coordination system using action potentials became possible. Glass sponges have managed to survive in the deep sea because they have low energetic costs. They have little tissue to maintain - the syncytial tissue is reduced to a thin veneer on a scaffolding of spicules. Thin syncytial tissue allows them to take advantage of passive flow for feeding, using ambient currents to draw more water through their body with no additional energy expenditure. However, becoming syncytial meant the loss of the contractile ability common to all other sponges, which is needed to clear canals of irritants or clogging. Since they could not contract effectively, syncytial sponges needed a way to avoid clogging altogether. What arose was an elaboration of what was likely an ancestral calcium-based action potential that each individual cell could do. This action potential, when propagated across the continuous membrane of the syncytium, could trigger an arrest of flagellar beating across the whole animal and thereby cease water flow through the canals of the aquiferous system. We propose that the evolution of action potentials as a coordination system occurred indirectly as glass sponges became specialized to live in the deep sea. Glass sponges present an interesting case of how an 'alternative' to nervous systems has evolved.

38.3 KAHRL, A.F.*; JOHNSON, M.A.; COX, R.M.; University of Virginia, Trinity University; *afk7df@virginia.edu*

Both pre- and postcopulatory selection shape the evolution of sperm morphology across Anolis lizards

Sexually selected traits exhibit remarkable diversity within and among species, much of which can be explained by selection before mating (precopulatory) or selection after mating (postcopulatory). These two episodes of selection interact and may independently influence the evolution of sexually selected traits. Sperm are highly diverse across species, and this diversity has traditionally been thought to be due to postcopulatory selection. To determine if both pre- and postcopulatory selection are associated with diversity in sperm morphology we tested for correlated evolution between testis size, dimorphism and sperm morphology among species of lizards. We collected sperm morphology from 29 species of *Anolis* lizards that encompass a wide range of both testis size and dimorphism. We measured the length of the sperm head, midpiece, and tail of 15 cells for 5-20 individual males per species. Using phylogenetically controlled methods we tested for correlations between testis size, and sexual size dimorphism and sperm morphology. We found that mean sperm midpiece length was positively correlated with testis size, and that variance in length of the sperm tail was positively correlated with male-biased dimorphism. This suggests that postcopulatory selection selects for larger midpiece size, while precopulatory selection may constrain postcopulatory selection from purging the variation from tail length. We also calculated the Brownian rates of evolution of the head, midpiece, and tail and found that sperm midpiece length evolves 2-3 times faster than other traits in our dataset. This suggests that the midpiece has experienced strong positive selection across species, potentially because it contains the cells mitochondria which are important for sperm function.

29.3 KAJI, T*; ANKER, A; WIRKNER, CS; PALMER, AR; Univ. of Alberta, Edmonton, Museu Paraense Emílio Goeldi, Brazil, Universität Rostock, Germany; *flickloop@gmail.com*

Evolutionary Origin of "Snapping" Shrimps: Crossing the Gap Between Pinching and Snapping Claws

Snapping claws, which occur in both alpheid and palaemonid shrimps, are spectacular offensive weapons that create intense cracking sounds and shockwaves toward prey and opponents. True snapping involves: a) rapid claw closure facilitated by an energy storing mechanism at the joint, b) creation of a cavitation bubble, and c) destructive shock waves induced by cavitation bubble collapse. How such an extraordinary weapon evolved from ordinary pinching claws is not known. We examined claw form in over 100 species of caridean shrimp including several snapping taxa using modern visualization techniques (e.g., micro-CT, confocal microscopy). This survey revealed a unique type of energy storage mechanism in the snapping claw of basal Alpheidae and Palaemonidae: a "slip-and-cock system" similar in form to the "slipjoint" widely shared by non-snapping caridean shrimp. To assess the relation between form and function we conducted physical experiments using enlarged, 3D printed scale models of different claw types. These experiments revealed a minute yet functionally significant quantitative difference in joint structure that clearly demarcates pinching from snapping claw function. This previously unrecognized slipjoint in non-snapping caridean shrimp claws appears to be an evolutionary precondition for the subsequent evolution of spectacular snapping claws.

48.5 KAJIURA, SM*; BERQUIST, RM; MEREDITH, TL; FRANK, LR; Florida Atlantic University, University of California San Diego; *kajiura@fau.edu*

Diffusion Tensor Magnetic Resonance Microscopy Reveals Novel Olfactory System Neural Organization in the Atlantic Stingray, Dasyatis sabina

All life on earth exhibits some degree of chemical sensitivity. Within the vertebrate clade, the organization of the olfactory system is largely conserved, despite their morphological diversity. Histological evidence suggests that the elasmobranch fishes demonstrate a remarkably different olfactory bulb organization than other vertebrates, including the teleost fishes. However, conventional histology is laborious, destroys intact structure, results in disjointed samples which must be reconstituted to elucidate three dimensional organization, and thus is inherently prone to tissue damage and registration errors. Here we show that Diffusion Tensor Microscopy (DTM) can be applied to facilitate Fiber Tract Mapping (FTM) of complex peripheral and central neural pathways. Using this non-invasive 3D digital imaging methodology, we imaged the olfactory organ and olfactory bulb of a basal vertebrate, the Atlantic stingray, *Dasyatis sabina*. We found that Olfactory Receptor Neurons (ORNs) project from the olfactory epithelium through the secondary and primary olfactory lamellae to the olfactory bulb. Within the bulb, the ORNs maintain their spatial integrity by projecting to glomeruli situated within one to two lamella widths of their point of origin producing a somatotopic bulbar organization. This contrasts with teleost fishes which possess a chemotopic organization whereby olfactory receptor neurons that share similar chemical sensitivity converge in glomeruli regardless of their point of origin within the olfactory epithelium. Our results illustrate the utility of DTM and FTM to efficiently inform us about intact neuronal structure by revealing a three dimensional bulbar organization that we believe may be fundamentally different from all other vertebrates.

119.2 KALISZEWSKA, ZA*; SANTANA, SE; RIFFELL, JA; University of Washington; *zakalisz@gmail.com*

Plants talking to bats: Chemical diversity of Piper scents

Chemical signals are key mediators of many ecological interactions, and are particularly important for fruit localization and selection by frugivores. Piper is a Pantropical plant genus that exhibits mutualistic interactions with bats in the Neotropical portion of its range. Though Piper scents attract bats to ripe fruits, little is known about the chemical composition, diversity, and evolution of these signals in the context of biotic interactions. To address this gap, we quantified the chemical composition of scents produced by ripe fruits, unripe fruits and vegetation of 26 species of Neotropical Piper using dynamic headspace adsorption and gas chromatography-mass spectrometry techniques. We found that Piper species that are consumed by bats have a similar chemical composition of fruit scents, but fruits of most Piper species have distinct signatures defined by their most abundant volatile organic chemicals. These include sesquiterpenes and monoterpene hydrocarbons such as apiol, cubebene, caryophyllene and safrole, some of which are involved in diverse ecological processes such as pollination, herbivory and frugivory in other systems. The scents of ripe fruit, unripe fruit and vegetation are more similar within than among Piper species. However, scent bouquets of each plant part are also distinct. Therefore, we predict that bats cue in on a general Piper scent, and then choose ripe fruits and particular species based on signals constituted by the most abundant and distinct volatiles.

P3.188 KALLENBERG, MK*; ZHANG, Y; HYATT, HW; KAVAZIS, AN; HOOD, WR; Auburn University; *mkk0009@tigermail.auburn.edu*

Reproductive effects on lipid transport capacity in liver and blood in rats

To support the high energetic demands of reproduction, female mammals display plasticity in many physiological processes, such as the lipid transport system. Lipids function as a substrate for supporting the female's energy demands and as a vital nutrient in milk. We hypothesized that key proteins which support lipid transport and mobilization will increase in level during pregnancy and lactation, but drop back to non-reproductive levels shortly after reproduction has ended. We characterized changes in pathways supporting fatty acid transport inside the liver, a key site of lipid storage and synthesis, and lipid delivery to tissues in reproductive Sprague-Dawley rats during late pregnancy, peak-lactation, 1-week post-lactation and in age-matched non-reproductive rats. Liver-type cytoplasmic fat transporter (L-FABP), plasma membrane fat transporter, fatty acid translocase (FAT/CD36) levels in the liver, and free fatty acid transporter albumin and triglyceride transporter (very low density lipoprotein) levels in blood serum were quantified. We found that albumin levels in serum was greater during pregnancy than non-reproductive rats. Lactating and post-lactating rats had significantly higher levels of L-FABP than their controls. Post-lactation rats had higher levels of FAT/CD36 than all other groups. These results indicate that fat transport capacities inside liver cells and in blood are elevated during lactation and pregnancy respectively. However, fat transport capacities were still higher than non-reproductive rats one week after lactation, which could be due to regression of the mammary glands after lactation and/or the mobilization of lipids stored during reproduction.

108.2 KAMRAN, M*; MOORE, ME; MOORE, PA; Oregon State University, Bowling Green State University, Baldwin Wallace University, Bowling Green State University; *mkamran@bgsu.edu*

Owners versus renters: comparative homing behaviors in primary and tertiary burrowing crayfish

Invertebrates and vertebrates alike exhibit wayfinding behaviors when locating and returning to sites of interest such as resource rich food patches or shelters. In particular, the ability to locate these sites successfully is critical for avoiding predation and acquisition of resources. While the spatial scale and the environment may differ and thus dictate the navigational strategy utilized, the task at hand is essentially the same, that is to return to a previously known location. With a rich behavioral repertoire and extensively studied nervous system, crayfish provide an ideal system for comparative research. While their spatial learning abilities and reliance on olfactory cues has been extensively studied, relatively little is known about their homing behaviors when returning to shelters. This study examined the homing behaviors of two comparative species of crayfish, both of which rely on burrows for shelter, while only one constructs them. The species were selected based on the varying degrees of complexity of the environments within which they reside as well as the amount of energy invested in constructing burrows. A homing error was induced by displacing the animals to determine their primary mechanism for homing and to determine whether there were any differences between the two species in terms of homing behaviors.

P1.284 KANE, EA*; ROEDER, MM; DERUE, ML; Georgia Southern University, Colorado State University, Colorado State Universtiy; *ekane@georgiasouthern.edu*

Swimming while feeding in fishes: What do guppies tell us about the roles of specialization and local adaptation?

Animals rely on coordinated and integrated behaviors to perform ecologically relevant tasks such as prey capture. In fishes, hydrodynamic properties predict that fishes with forceful suction cannot simultaneously swim fast. Because suction force increases as mouth size decreases, a tradeoff between mouth size and swim speed are expected. This relationship has been supported empirically in several clades of suction-feeding fishes, but may break down in fishes specialized for other feeding modes. However, testing the effects of feeding specialization on this integration has been difficult because previous comparisons have been between and among species, where secondary differences may confound interpretations, or individuals have not been required to perform comparable tasks. We test the effect of specialization on integration in two ways using Trinidadian guppies (*Poecilia reticulata*): 1) by examining integration in a species specialized for biting, but while capturing suspended live prey using suction, and 2) by examining differences in integration between locally adapted, divergent populations within this species. These tests allow for direct comparisons with other previously studied suction-feeding fishes while also limiting the effects of evolutionary divergence when interpreting differences in patterns. Evidence of integration would demonstrate that the constraints of suction are a broad and due to the mechanics of suction. Alternatively, a lack of integration would support the hypothesis that specialization for an alternative feeding mode might limit the ability to coordinate tasks.

P1.188 KAPLAN, SA*; POWERS, AK; GROSS, JB; University of Cincinnati; *kaplansa@mail.uc.edu*

Understanding the Origin of Cranial Bone Fragmentation: Live-fluorescent Imaging Across Astyanax mexicanus Development

The blind Mexican cavefish, *Astyanax mexicanus*, is a natural model system for regressive evolutionary change. These fish have evolved various extreme morphologies as a consequence of life in total darkness. Adult cavefish exhibit cranial aberrations that impact the bones encircling the collapsed eye orbit. These dermal bones demonstrate fragmentation marked by the incomplete fusion of multiple smaller bony pieces. This contrasts with the single bones present in the extant surface morphotype. Yamamoto *et. al.* (2003) showed that juveniles of both morphotypes develop from a single condensation of mesenchymal cells, i.e., the primary ossification center. In surface fish, this center expands into an intact third suborbital (SO3) bone. In cavefish, however, they observed multiple secondary ossification centers that form, based on analyses of fixative-preserved specimens. To understand the developmental basis of facial bone fragmentation, we performed an intra-individual live-staining procedure involving the bone-specific stain, Calcein. This enabled us to document dynamic features of bone growth and reabsorption. We quantified differences in the size (area growth over time), shape, and presence/absence of ossification centers within individual cavefish. This work reveals dynamic changes to the cranial complex in cavefish over the course of their development, and provides the opportunity to better understand the precise molecular, genetic and developmental features underlying these cranial abnormalities.

P1.134 KASS, HR*; SANDVIK, GK; FONTAINE, R; WELTZIEN, FA; BAKER, DM; University of Mary Washington, Fredericksburg, VA, Norwegian University of Life Sciences, Oslo, University of Mary Washington; *hkass@umw.edu*
The Effect of Kisspeptin 1 on Gonadotropin Releasing Hormone Neurons in Embryonic Medaka (Oryzias latipes)
In mammals, the neuropeptide kisspeptin stimulates the release of gonadotropin releasing hormone (GnRH) and thereby regulates sexual maturation and reproduction. Increasing evidence indicates that kisspeptin homologues may play a similar role in teleosts. In medaka, as in other teleosts, multiple homologues of kisspeptin are expressed. Previous research has shown that the gene endoding the Kiss1 homologue is expressed throughout medaka embryonic development, but its function in embryogenesis is unknown. Based on the known relationship between kisspeptin and GnRH in other vertebrates, we hypothesized that Kiss1 plays a role in the development of GnRH neural network in embryonic medaka. We tested this hypothesis by exposing medaka embryos to Kiss1 or a Kiss receptor blocker and examining the effects on GnRH neuron development and *gnrh* expression throughout embryogenesis. To test whether Kiss1 affects GnRH neuronal proliferation and migration, we treated GnRH-1 promoter:GFP transgenic embryos, collected them at 2-8 days post fertilization, then mapped and quantified GFP-labeled neurons. In preliminary analysis of 4-day embryos, neuron number varied from 19 ± 6.8 (mean ± SD) in controls, to 22 ± 6.9 in Kiss1-treated embryos and 16 ± 4.6 in blocker-treated embryos (n=6). These differences were not significant, however, (ANOVA; p = 0.3) indicating that Kiss1 signaling does not regulate GnRH-1 neuron proliferation or differentiation at this stage. To examine the effects of Kiss1 on *gnrh-1* and *gnrh-3* expression, we collected control, Kiss-1, and blocker treated wild-type embryos throughout embryogenesis and are quantifying *gnrh* expression with qPCR.

81.2 KATHMAN, ND*; FOX, JL; Case Western Reserve University; *ndk9@case.edu*
Haltere and visual information processing in the central complex of the fly brain
The reduced hindwings of flies, known as halteres, are specialized mechanosensory organs that are essential for flight. Through arrays of strain-sensitive sensilla on their bases, halteres detect inertial forces associated with body rotation during flight (Nalbach 1993; Dickinson MH 1999). Previous studies have shown direct haltere inputs to both wing-steering and neck motoneurons (Fayyazuddin and Dickinson 1996; Chan and Dickinson 1996), but there is currently no evidence of haltere stimulus representation in the brain, where body rotation information could be integrated with other sensory inputs. As in the vertebrate vestibular system, the haltere system interacts with vision to control body and head movements. Behavioral work done in our lab has shown that halteres are important for mediating wing-steering responses to wide-field motion (Mureli & Fox 2015). This visual stimulus is also encoded in the central complex (CX), an associative sensorimotor integrating region in insect brains (Weir and Dickinson 2015). Whereas fast flight maneuvers require direct neural connections from haltere afferents to flight steering muscles, it is also possible that integration of visual and haltere information may take place in the brain which can be used in various tasks, such as longer-term planning. Using multichannel extracellular recording, we examined responses of CX cells to various haltere and visual motion stimuli. Some CX cells showed non-linear, speed-dependent responses to both haltere and visual input. We also quantified the modulation of these responses by simultaneous stimulation in both modalities. By showing how haltere information is represented and integrated in the central brain, we provide the first evidence of ascending input into the CX and demonstrate how multi-modal information can be used to support locomotor or other complex behaviors.

60.4 KATIJA, K*; SHERMAN, AD; SHERLOCK, RE; ROBISON, BH; Monterey Bay Aquarium Research Institute; *kakani@mbari.org*
Giant larvaceans: Differences in tail kinematics lead to enhanced filtration rates in mucus houses
The midwater region of the ocean (below the euphotic zone and above the benthos) is one of the largest ecosystems on our planet, yet remains one of the least explored. Little-known marine organisms that inhabit midwater have developed life strategies that contribute to their evolutionary success, and their ecology is largely unknown. A group of midwater organisms, known as giant larvaceans (genus *Bathochordaeus*), beat their tails to drive food and particle-laden water through complex, mucus filtering structures to feed. Giant larvaceans, whose motion and kinematics resemble flapping flexible foils, range in size from 1 to 10 cm in length, and can be found between the surface and 400 m in Monterey Bay. Using remotely-operated vehicles and DeepPIV, an instrument that enables in situ particle image velocimetry (PIV) measurements, larvacean filtration rates were found to be as high as 80 L/hr, exceeding expected filtration rates by a factor of 2. Comparing tail kinematics between two *Bathochordeaus* species reveals differences in tail bending modes that contrast with expected bending modes in biological flexible propulsors. By conducting laboratory PIV measurements on swimming animals and soft-bodied mechanical models, we reveal how these differences in tail kinematics can not only lead to enhanced fluid transport to improve feeding, but also play a role in inflating the complex mucus houses they inhabit.

48.7 KATZ, HR*; HALE, ME; Univ. of Chicago; *katz20h@uchicago.edu*
Characterizing the transition from axial to limb-based startle through metamorphosis in the frog Xenopus laevis
Although the The Mauthner cell (M-cell) and its neural circuit are best known for driving the startle response of fishes, some amphibians also have M-cells. One such species is *Xenopus laevis*, the African clawed frog, which has M-cells at the tadpole and adult life stages. These animals have drastically different startle behaviors before and after metamorphosis: an axial startle response as a tadpole and a limb-based response as an adult. Furthermore, the animal must also perform the startle response during metamorphosis, but how this change in behavior occurs through these intermediate developmental stages has not been characterized in depth. By investigating whether the transition in startle is a discrete or gradual behavioral shift, we can begin to form hypotheses about how the Mauthner circuit itself might be changing to accommodate a tetrapod body plan. We performed high-speed video recordings of *X. laevis* startle at stages ranging from pre-metamorphic tadpole to adult frog. Our preliminary observations are based on 20 animals ranging between stages 47 and adult. During early hindlimb development (stage 57), limbs tend to remain close to the body axis throughout the duration of the C-bend behavior. Around stage 60, the hindlimbs appear to be involved in the first stage of startle; however, unilateral axial movement still appears to be the primary mode of propulsion. Between stages 61-63, the limbs become the primary propulsors of the startle response. These observations indicate a gradual shift in startle behavior and that M-cells may be transitioning from primarily unilateral activity to bilateral activity to initiate limb movement.

P2.106 KAUNISTO, S*; FERGUSON , L V; SINCLAIR, B J; University of Western Ontario; *sirpa.kaunisto@uef.fi*
Can We Predict the Impacts of Multiple Stressors on Insects in a Changing Climate?
Insects and other organisms must respond to various natural stressors, but also to increasing array of anthropogenic stressors. Climate change and other stressors form a complex multi-stressor environment with many potential interactions between stresses. The responses and resistance of organisms to climate change will depend on their responses to combinations of stressors, which may or may not reflect responses to single stressors in isolation. Although important, combined effects of multiple stressors are particularly difficult to study and there are many examples on interactive and counterintuitive effects of multiple stressors, which leads to the concern that their complexity will make accurate predictions of the consequences of anthropogenic change impossible. We surveyed the Anglophone literature, and provide an overview of the current knowledge on the impacts and interactions of different stressors in insects. Although synergistic stressor interactions (resulting in a greater-than-expected impact) appear common among insects, the thin taxonomic spread of existing data means that more multi-stressor studies and new approaches are needed. Multiple stressor studies, especially with three or more stressors, are fairly rare. Published multiple stressor research is still mainly of phenomenological and descriptive in character, missing mechanistic, predictive understanding. Further, we must identify which stressor interactions, and species' responses to them, are generalizable (i.e. most or all species respond similarly to the same stressor combination), and thus predictable (for new combinations of stressors, or stressors acting via known mechanisms). We discuss experimental approaches that could facilitate this shift towards predictive understanding of multiple stressors.

P3.127 KAWANO, DK*; GEORGE, SB; University of Washington, Seattle, WA, Georgia Southern University, Statesboro, GA; *georges@georgiasouthern.edu*
The effect of Low Salinity Events on Protein Expression and Feeding in Pisaster Larvae
The keystone species *Pisaster ochraceus* plays a fundamental role in preserving biodiversity in Pacific intertidal ecosystems. Unfortunately, the increasing frequency and intensity of low salinity events in places like the Salish Sea is of growing concern for developing *P. ochraceus* larvae. Previous studies have shown that larvae reared in low salinity conditions become short and wide and their swimming ability is impaired. To further characterize how *P. ochraceus* larvae are affected by low salinity, I investigated how single and multiple low salinity events affect protein expression and feeding. Coomassie stained NuPAGE™ gels revealed that several proteins were expressed at equal levels regardless of salinity treatment; these included anion transporters and Na^+/K^+ ATPase. Other proteins, such as NADPH oxidase and Ca^{2+} ATPase, were up-regulated when larvae were exposed to multiple low salinity events, especially after four low salinity events. After a 24-hour low salinity event, larvae consumed fewer algal cells, demonstrating a reduced feeding ability. The difference in expression for the various osmoregulatory proteins and observed effect on feeding ability has implications for how *P. ochraceus* larvae can respond to frequent hypoosmotic stress.

P1.166 KAWARASAKI, Y*; WELLE, AM; ELNITSKY, MA; Gustavus Adolphus College, Mercyhurst University; *ykawaras@gustavus.edu*
Oxygen Consumption During the Induction of Rapid Cold-Hardening in Isolated Muscle of Flesh Fly, Sarcophaga bullata
Rapid cold-hardening (RCH) describes an extremely swift response of insects to enhance their cold tolerance. A brief exposure to a moderately low temperature dramatically increases insect survival to a subsequent cold exposure that would be lethal otherwise. In the flesh fly, *Sarcophaga bullata*, as little as 15 min at 5°C significantly improved organismal survival at -7°C from 0 to 66.7±11.1%. Previous studies have demonstrated that the induction of RCH occurs at the cellular level through calcium signaling and activation of p38 MAP kinase. In this project, we examined the changes in the oxygen consumption during the RCH induction, using isolated flight muscles of *S. bullata*. Compared to tissues that had been maintained at 5°C for 2 h, those at 5°C for 10 min, therefore during the early phase of RCH induction, exhibited significantly higher rates of oxygen consumption (1.18±0.09 vs. 2.82±0.29 µl O_2 mg^{-1} DM h^{-1}). When these tissues were exposed to $LaCl_3$, blocker of calcium channels that has been previously described to inhibit the RCH response, their oxygen consumption rates were reduced significantly to a level similar to those that had been maintained at 5°C for 2 h. Our initial results suggest that the high rate of oxygen consumption is associated with the RCH induction, likely to meet the energetic demand of eliciting this protective response.

P1.215 KAY, DI*; ERICKSON, GM; KUHN-HENDRICKS, SM; Florida State University, Florida State Univeristy; *dkay@bio.fsu.edu*
Evolution of Mineralized Dental Tissue Material Properties
As gnathostomes diversified, modifications to dental form and mineralized tissue constituents (enamel, dentines and cementum) facilitated a variety of trophic niches. Previous assumptions that non-mammalian tissue-level mechanics of these components had little bearing on whole-tooth functionality. Mammals possess teeth that functionally self-wear and show a diversity of derived tissues which possess unique mechanical attributes. We tested the hypothesis that the material properties of non-mammal dental tissues are uniform. We then explore how those have changed with mammalian cladogenesis and how dietary and dental morphology changes correlate with tissue-level mechanics through the gnathostome radiation. We used microindentation techniques to test dental tissues from representatives of major taxonomic clades, determining Young's modulus (E), Vicker's hardness (HV), and crack channeling (CC). These data were mapped onto a phylogeny for Gnathostomata and analyzed in evolutionary and ecological contexts. Results show that properties of non-mammals show substantial intercladal variation. For example enamel E and HV values are low in squamates and neopterygii, and high in chondrichthyans, archosaurs and therians. Non-eutherian enamels isotropically fracture and are prone to catastrophic failure. However, eutherian enamel (excluding cetaceans) exhibits CC associated with enamel prism fabrics, localizing damage. Orthodentine HV and E values mimic the patterns of the enamels, but show greater sub-cladal variability. The results show that dental tissue material property variation in non-mammalian gnathostomes, like mammals is considerable, suggesting that selection acted at the tissue-level to convey differences in tooth functionality throughout the gnathostome radiation.

P1.242 KEEFFE, RM*; DIAMOND, KM; LAGARDE, R; PONTON, D; BERTRAM, RS; SCHOENFUSS, HL; BLOB, RW; University of Massachusetts, Amherst, Clemson University, Hydrô Réunion, UMR Entropie, St. Cloud State University; *rkeeffe@umass.edu*

Comparative Waterfall Climbing Kinematics of Goby Fishes from Hawai'i and Réunion: Are Recently Evolved Behaviors Less Variable?

Several gobiid stream fishes climb waterfalls as juveniles during their amphidromous life cycle. Previous research identified two climbing styles: powerbursting and inching. Powerburst climbers use pectoral fin adduction and bursts of axial undulation to propel themselves upwards between periods of attachment to the substrate with a pelvic sucking disc. Inching climbers sequentially detach and reattach both pelvic and oral sucking discs to climb, with little axial movement. Powerburst movements represent the ancestral style of climbing in gobies, providing more time for their kinematics to diversify. As a result, we expect to observe higher kinematic variation between powerburst species than between inching species. To test this prediction, we compared previously collected, high-speed video data on climbing kinematics from juveniles of powerburst (*Awaous stamineus*, *Lentipes concolor*) and inching (*Sicyopterus stimpsoni*) species from the Island of Hawai'i, to new data from powerburst (*Cotylopus acutipinnis*) and inching (*Sicyopterus lagocephalus*) species from the Indian Ocean Island of Réunion. Powerburst climbers showed notable variation in climbing kinematics across species, with divergent ranges of maximum amplitudes and velocities of body segments, and the angles of segments to the direction of travel. In contrast, inching kinematics were similar across species with regard to oral sucker expansion and timing of head and pelvic sucking disk advancement. These patterns suggest that limited evolutionary time, and potentially constrained mechanics of the oral sucking disk, may limit the diversification of inching movements.

P3.151 KEEGAN, A*; FREDERICH, M; Univ. of New England, Biddeford; *akeegan@une.edu*

The effect of fear to be eaten by green crabs (Carcinas maenas) on the morphology and physiology of soft shell clams (Mya arenaria)

The invasive European green crab has detrimental effects on soft shell clam (*Mya arenaria*) populations and clam fisheries have collapsed due to green crab invasions. Growing evidence supports the idea that trophic interactions between predator and prey have the ability to alter morphological and physiological. These shifts in prey species have the potential to alter future predator/prey interactions. This project investigates morphological and physiological changes in both juvenile and young adult soft shell clam populations when subjected to varying densities of green crab presence. Juvenile and young adult clams were exposed to green crab chemical cues in three different densities: control (no crabs), low predation (3 crabs/0.15m^2), and high predation (7 crabs/0.15m^2). Juvenile clams were exposed to the crabs for six months, and the young adult clams for 72 hours. Juvenile clams were measured for shell length, siphon length, AMPK activity, HSP70, and RNA:DNA ratio, while young adults were tested for AMPK, RNA:DNA ratio, HSP70, shell opening, heart rate, and oxygen consumption (last three adult parameters tested with varying levels of both predator and conspecific chemical cues). First results for juveniles exhibit increased siphon length and reduced siphon thickness, as well as reduced shell length in the low predation density. Exposing adult clams to predatory chemical cues leads to reduced frequency of shell opening. Ongoing analyses of cellular stress parameters explore the underlying cellular mechanism. Our preliminary results indicate that the presence of predators affects growth rates and/or energy utilization in clams, with subsequent effects on the shellfish industry.

P3.57 KEER, S*; HERNANDEZ, LP; The George Washington University; *skeer@gwu.edu*

Late embryonic and larval development of the cypriniform palatal organ

The feeding novelties of cypriniform fishes are responsible for the success of this group in freshwater within a variety of ecological niches. The palatal organ (PO) is one of these novelties, a muscular pad located on the pharyngeal roof that is used in feeding. It has been found in all cypriniform fishes that have been examined, despite previous studies that correlated a large vagal lobe with the presence of a palatal organ. Previous research using carp and goldfish has shown that the PO is innervated by the vagus nerve and used for manipulating and sorting through detritus, as well as potentially being used in suction feeding, but despite its importance, a careful study of the early developmental origin and growth has not yet been undertaken. Therefore the zebrafish, *Danio rerio*, a well-characterized cypriniform model organism, was used to trace the development of the PO through late embryonic, larval, and early juvenile growth as the PO fully develops and is innervated. As the yolk is absorbed and *D. rerio* switches to exogenous feeding, disorganized fast muscle fibers begin to form between the extraocular muscles at approximately 6 days post fertilization. These fibers grow caudally across the pharyngeal roof towards the branchial arches. The disorganized fibers form a tangled web that may allow the palatal organ to function as a hydrostat capable of forming localized protrusions in multiple directions. These data suggest that from an early age, D. rerio may be using the PO to suction feed and/or manipulate prey items. Understanding the development of the PO will help elucidate how it has become incorporated into the entire feeding apparatus of cypriniform fishes and may also help explain how this group has so successfully invaded so many trophic niches.

21.5 KEISER, CN*; PRUITT, JN; Rice University, University of California, Santa Barbara; *cnkeiser@gmail.com*

Personality composition alters bacterial transmission dynamics in spider societies

The frequency and nature of social interactions during the early stages of a disease outbreak can determine the magnitude of the potentially ensuing epidemic. Two factors which may have a strong influence over these interactions are (1) the composition of behavioral phenotypes among the susceptible population and (2) the behavioral traits of the index case (i.e. 'patient zero'). Unfortunately, these two factors are rarely examined in unison. Here, we test whether the personality composition of social groups can explain the horizontal transmission dynamics of a cuticular bacterium, *Pantoea* sp., in the social spider *Stegodyphus dumicola*. We topically exposed focal spiders of known behavioral types (i.e., bold or shy personality types) with GFP-transformed *Pantoea* and allowed them to interact with groups of 10 susceptible individuals with no previous experience with the transformed bacterium. We estimated the bacterial transmission that occurred in groups composed of either all shy spiders, 10% bold spiders, or 40% bold spiders. We found that colonies with 40% bold spiders experienced over twice the incidence of transmission compared to colonies with just 10% bold individuals after only 24 h of interaction. Colonies containing all shy spiders experienced an intermediate degree of transmission. Interestingly, we did not detect an effect of the traits of the index case on these trends. Thus, perhaps the phenotypic composition of the susceptible population can have a stronger influence over the magnitude of early, rapid transmission events compared to the behavioral traits of the index case.

P2.37 KELLEY, MD*; MENDONCA, MT; Auburn University; *mdk0014@auburn.edu*

Reproductive behavior patterns and sensory perception in Gopher Tortoises

Gopher tortoises display large chin glands that have been suggested to be a courtship cue, through visual gland size or production of olfactory signals. Little is known about the function of this gland except that males have larger glands than females. While males are thought to use head bobbing to transmit odors via these glands to attract females or ward off other males, females only head bob in courtship, suggesting a potential sexual dimorphism in sensory awareness of chin gland cues. In this study, courtship and male competition were simultaneously observed in presentation (non-visual and visual) of a female with two males of differing sized chin glands (N=5-7). Types and duration of behaviors were recorded during 10 minute trials during the tortoise breeding season (April-September) and classified into 3 categories: regulatory (eating), stress (pacing), or awareness (sniffing, awareness of other conspecifics). A significant behavior category*month interaction was found in which both sexes (sexes did not differ by month in behavior category, p=0.74) exhibited more stress behaviors in April than in June and more awareness behaviors in June than in April (p=0.003). In August, both sexes exhibited more awareness behaviors, while in September, they displayed more regulatory behaviors (p=0.03). Because chin glands also show a seasonal pattern of growth, with enlargement in June and regression in September, this glandular regression coincided with a shift toward regulatory behavior, suggesting hormonal control. There was also a sex*treatment interaction seen between April, June, and July due to female tortoises exhibiting stress behaviors in the non-visual presentation in June (p=0.05). Furthermore, both males and females spent more time sniffing during the non-visual presentations than in the visual presentations (p=0.02). While males did sniff more than females over all months, dimorphism in active sniffing was not found (p=0.55).

5.1 KELLY, MW*; YOON, A; Louisiana State University; *morgankelly@lsu.edu*

Protein coding and regulatory variation contribute to heat adaptation in the copepod Tigriopus californicus.

Both protein coding and regulatory variation may contribute to local adaptation to the abiotic environment. We tested for contributions of each of these to heat adaptation in the copepod *Tigriopus californicus* by hybridizing populations that were divergent for heat tolerance, and then selecting for increased heat tolerance in hybrids over ten generations. Heat-selected lines had greater heat tolerance, but also diminished plasticity of gene expression and greater baseline expression of transcripts involved in the plastic response to heat stress. Genotyping of heat-selected lines also revealed increased frequencies of southern alleles for several genes, most notably for heat shock protein 70. Our results are consistent with findings from an array of other taxonomic groups, suggesting that both coding sequence variation and changes in gene regulation typically contribute to intraspecific variation in environmental tolerance.

S9.10 KELLY, Aubrey*; OPHIR, Alexander; Cornell University; *amk297@cornell.edu*

The influence of family dynamics on developmental trajectories and modulation of social behavior in prairie voles

The nonapeptides vasopressin (VP) and oxytocin (OT) are two of the most important influences on the social brain, and are known to modulate a wide variety of social behaviors including pair bonding and affiliation, social recognition, aggression, and anxiety-like behavior. Surprisingly, little is known about the functional development of the nonapeptide system and the influence of the early life family environment on the social brain and behavior. In order to investigate early social functioning of VP and OT cell groups, we examine the response of nonapeptide neurons in prairie vole pups (Microtus ochrogaster; a socially monogamous and biparental rodent) to parental separation at different ages across early development. In addition, although there is extensive data examining the effects of maternal separation on pup development, there is extremely little data investigating the effects of paternal deprivation on the development of social behavior. In order to examine the impact of paternal care on development of social behavior, we raised pups in biparental or single mother families. Once pups reached adulthood, they were tested for various social behaviors including social approach and recognition, dominance behavior, and pair bonding. Lastly, because separation from one or both parents should impact both the offspring and the parents, we examined the effects of offspring separation on VP-OT responses in mothers and fathers and the impact of being a single parent on maternal behavior.

14.1 KELLY, D.A.*; MOORE, B.C.; University of Massachusetts, Sewanee: The University of the South; *dianek@psych.umass.edu*

Structural and Functional Differences in the Penile Tendons of the American Alligator (Alligator mississippiensis)

Two collagenous structures, the ventral penile tendon (VPT) and the ligamentum rami (LR), are critical to normal phallic eversion and retraction in male American alligators (*Alligator mississippiensis*). Both structures connect the phallus to the ischium, but they have different functional roles. The VPT anchors the phallus in the cloaca and acts as a fixed point around which the phallus rotates during eversion and retraction; the paired LR are thought to act as a spring that returns the phallus to its resting orientation after eversion. Tensile tests of both tissues indicate that although both the VPT and the LR have a J-shaped stress-strain curve characteristic of collagenous tissues, the LR are more extensible than the VPT and have a Young's modulus that is approximately an order of magnitude greater. Histological examination reveals that both the VPT and LR are primarily made up of Type I collagen fibers but the arrangement of collagen inside the tissue differs. Collagen fibers in the LR are long and arranged parallel to the long axis of the structure, while collagen fibers in the VPT are shorter and arranged in an interconnected three-dimensional network. The differences in the mechanical behavior of the VPT and LR during penile eversion and retraction may therefore be the result of differences in collagen fiber arrangement within each tissue rather than differences in material composition.

56.2 KEMBERLING, A.A.*; DARNELL, M.Z.; University of Southern Mississippi; *Adam.Kemberling@usm.edu*

Regional Migration Patterns of Mature Female Blue Crabs in the Gulf of Mexico

Female blue crabs undertake a seaward spawning migration, migrating from low-salinity mating grounds to high-salinity areas where spawning takes place. While the estuarine portion of the migration has been subject of much research, little is known about movement once crabs leave the estuaries. Offshore migration patterns and spawning locations determine the ultimate settlement location of offspring, which are transported passively by currents during most of their larval period, and thus drive connectivity patterns among estuaries. In March, 2016, we began a Gulf-wide mark-recapture study to examine regional-scale migratory patterns of the Gulf of Mexico blue crab spawning stock. 4,000 female blue crabs have been tagged on their journey towards high-salinity waters where they spawn. 640 crabs have been recaptured at this time, a 16% recapture rate, with numerous individuals recaptured after crossing state boundaries. Each tag possesses a unique identification number, an offer of a monetary reward, and instructions for reporting recaptured crabs and claiming the reward. A dedicated phone line, web page, and voice mailbox are available 24/7 for the reporting of captured crabs. We have also conducted directed trawl surveys in offshore areas known to be spawning habitat for female blue crabs. In addition to geographic data, reproductive analysis on females acquired from known estuaries is being completed to assess regional reproductive potentials. This project involves collaboration with state agencies, commercial crabbers, and educators, and results will help identify the extent of connectivity versus isolation of the Gulf of Mexico spawning stock(s), and the subsequent implications for larval dispersal and recruitment.

14.5 KENALEY, C*; SANIN, A; Boston College; *kenaley@bc.edu*

Mechanics of Fish Skin: Contrasting Material Properties Within and Between Functional Systems

The skin of non-tetrapod fishes provides several important functions, including protection from the external environment, water balance, and gas exchange. The role skin plays in biomechanical systems such as locomotion and feeding has received little attention by scientists. With its cross-helical arrangement of collagen fibers, fish skin may contribute to swimming by maintaining hydrodynamic body shape and serve as a lateral tendon that increases the mechanical advantage of the body musculature and stores elastic energy. The material properties of fish skin that underlie these functions have been explored in detail in only a few species of sharks, an eel, and a limited number of percomorph fishes. In this study, we tested uniaxial, longitudinal stiffness along the entire trunk of three species of teleost fishes---a salmon, lutjanid snapper, and pompano. We also undertook uniaxial testing of the hyoid skin form our lutjanid snapper species. Based on over 300 strain experiments, we found that uniaxial stiffness increases along the anterior-posterior axis of the trunk in all three species. Skin from the trunk of the snapper skin was only approximately 5 times as as stiff as skin from the hyoid region. We also found that trunk skin stiffness varies considerably between species with pompano having the stiffest skin, 60 times more stiff than sockeye salmon, the least stiff of our study species. Combined, our findings of a stiffness gradient along the trunk and that fishes with faster swimming performance have much stiffer skin indicate that skin plays an important role in transmitting force during body-caudal fin propulsion. The dramatic differences in skin stiffness between skin samples from feeding and locomotor systems also suggest that skin material properties can be tuned to specific performance and behavioral goals.

P1.211 KENNEDY, EBL*; PATEL, RG; UYENO, TA; CLARK, AJ; College of Charleston, Valdosta State University ; *kennedyeb@g.cofc.edu*

Material Properties of Hagfish Skins Under Equibiaxial and Nondestructive Uniaxial Tension

Slack skin is a proposed adaptation for the peculiar knotting mechanism in hagfishes, as the loose covering enhances flexibility of the poorly attached body core. Hagfish skins are biological composites comparable in strength and stiffness to the taut skins of other fishes. The skins of all hagfish species are comprised of a fibrous dermis arranged between a superficial thin slimy epidermis and a thick fatty hypodermis, however, the material properties of the skins differ across species; Pacific hagfish skins are anisotropic, being more compliant in the circumferential axis than in the longitudinal axis, while the skins of Atlantic hagfish are isotropic. However, these data were gathered from uniaxial tensile tests to failure, whereas fish skins normally operate under biologically relevant stresses and strains, cyclically absorbing and releasing energy without mechanical failure. Furthermore, knot tying involves concurrent bending and twisting along multiple body axes. Here, we 1) measured a non-destructive property, resilience, of hagfish skins strained by 10% in longitudinal and circumferential axes, and 2) measured the strength, stiffness, extensibility, and toughness of skins simultaneously strained along both body axes. Hagfish skins return only 30% of the energy absorbed and do not return to their original length, and skins shown to be isotropic under uniaxial tension are anisotropic under equibiaxial tension. The anisotropy in Atlantic hagfish skins strained biaxially is reminiscent of Pacific hagfish skins and contrasts taut fish skins, which are usually twice as stiff and strong in the circumferential axis. We propose that increased compliance in the circumferential axis of the skin does not inhibit the generation of torsion by the body core.

64.4 KENNY, MC*; GIARRA, MN; ROGERS, PS; BARNES, A; SOCHA, JJ; Virginia Tech, Breckenridge Middle School, Roanoke, VA; *mck66@vt.edu*

How temperature influences the viscosity of hornworm hemolymph

The insect circulatory system is responsible for the circulation of nutrients, hormones, and metabolic waste via the transport of hemolymph. The hemolymph also functions to close off wound sites, destroy internal parasites, and, in some cases, aid in thermoregulation. As ectotherms, insects are significantly affected by environmental temperatures, and have evolved multiple mechanisms to respond to temperature extremes. For example, some insects upregulate heat shock proteins in response to heat to minimize protein denaturation, and some increase glycerol production and purge water in response to cold to minimize ice crystal formation. However, the effect of temperature on the physical properties of hemolymph has not been studied, and changes in viscosity in particular may greatly influence an insect's ability to circulate hemolymph. Here, we used *Manduca sexta* larvae to measure the effect of temperature on the viscosity of hemolymph. Measurements were taken from 5-45 ºC at 5 ºC intervals using a cone and plate viscometer (Brookfield Engineering DV-II+ Pro) and an attached water circulator (Lauda RE206) to regulate temperature. To minimize oxygen-induced clotting, experiments were performed in a sealed glove box flooded with nitrogen gas. Preliminary results reveal that viscosity increased with decreasing temperature, showing an increase in average viscosity from 1.9 to 9.2 cP. This ~4x change is greater than that in water, whose viscosity increases from 0.8 to 1.5 cP in the same temperature range. This dramatic change in viscosity may represent an underappreciated factor in the reduction of activity with decreasing temperature. Supported by NSF 1558052 and 1301037.

P2.41 KESSLER, B.J.*; ELIAS, D.O.; Univ. of California, Berkeley; *benjik2013@gmail.com*

Do you have have to turn on the red light? The effects of lighting and substrate on the courtship success of a North American jumping spider

Complex multimodal signaling is prevalent in animal communication, but there remains very much to be explored regarding the function and evolution of such signaling systems. In this study I test the relative importance of different sensory modalities in determining courtship success in the jumping spider Habronattus formosus. Males of this species are notable for the presence of red third-leg ornaments, which are displayed during courtship dances, as well as for complex vibratory "songs" transmitted through the substrate as part of the courtship display. Male - female pairs were placed inside an enclosure in which both the lighting and vibratory environments were experimentally manipulated. Each pair was randomly assigned a substrate that either did or did not conduct vibratory "songs," as well as either a full-spectrum lighting environment or one in which long-wavelength light was excluded. The effects of both manipulations, in isolation and in tandem, on courtship behaviors and probability of mating were measured. Results of this study, when compared with similar studies of related groups of jumping spiders, can provide insight into the evolution and function of multimodal signals.

P1.260 KHANDELWAL, PC*; HEDRICK, TL; University of North Carolina at Chapel Hill; *pranavk@live.unc.edu*

The short and long of gliding

Natural habitats present gliding organisms with various challenges to negotiate as they move from one location to another in air. The glide target and execution may vary with behavior like seeking mates, avoiding predation, territorial aggression or foraging, and consequently determine the glide distance. Longer glides (L) require the animal to generate lift for a sustained duration and increase the probability of encountering obstacles in a cluttered environment. Shorter glides (S) may reduce the search area for mates and food but allow more careful selection of a landing site. Quantifying voluntary glides in a natural setting may provide insight into the outcomes of behavior on decision making and glide execution. We recorded short (< 4m) and long voluntary glides in a wild, freely-behaving population of the flying lizard *Draco dussumieri* and extracted kinematic profiles using 3D tracking (n=30). We identified three distinct glide phases - ballistic takeoff, glide and landing. Results indicate similar glide execution for short and long glides. The duration of the ballistic dive phase was comparable ($t(S)=0.37 \pm 0.05$ s, $t(L)=0.36 \pm 0.06$ s), with higher velocity and steeper descent angles in L compared to S. Extended glide and landing phases were seen in L with higher maximum velocities ($v(L) \sim 6.65$ ms^{-1}, $v(S) \sim 4.89$ ms^{-1}) and lateral maneuvering. We identified peaks in centripetal force during L which correspond to turns undertaken during the glide phase. Lastly, a linear relationship was found between the glide distance and the corresponding height lost. These results suggest that the decision to execute a short or long glide is made before or shortly after takeoff. However, the possibility still exists that short glides could be extended to long glides allowing the lizard to achieve higher velocities to facilitate maneuvering.

132.2 KHURSIGARA, A.J.*; JOHANSEN , J.L. ; ESBAUGH, A.J. ; University of Texas at Austin ; *akhursigara@utexas.edu*

The influence of oil exposure on social interactions and competition in a marine teleost

In resource limited environments fish compete and establish social hierarchies in which one fish is dominant and the other subordinate. Dominant fish are more successful at monopolizing resources and generally have higher fitness and survival, while subordinate fish suffer not only the loss of resources but also a cascade of negative physiological impacts as a result of chronic stress. Predictors for dominance vary between species but typically combine aspects of personality with physiological traits such as size difference, metabolic rate, and variation in circulating hormone levels. Interestingly, work in the Gulf of Mexico following the *Deepwater Horizon* oil spill has shown that exposure to low concentration of PAHs found in crude oil impairs several aspects of physiological performance, including aerobic scope and swim performance. This leads to hypothesis that individuals exposed to sub-lethal oil concentrations may be predisposed to subordination. We sought to explore this hypothesis using the economically important red drum, which is native to many of the habitats impacted by the *Deepwater Horizon* oil spill. Initial experiments validated the underlying mechanisms of hierarchy formation using a dyad competition test design, which demonstrated that dominant individuals had significantly higher aerobic scope than matched subordinates. Furthermore, exposure to environmentally realistic oil concentrations resulted in subordination. These data demonstrate that sub-lethal oil exposure can impact social status in red drum, which can result in a number of downstream ecological physiological consequences.

145.2 KILLPACK, TL*; MELON, LC; Wellesley College; *tkillpack@wellesley.edu*

Faculty Professional Development for Inclusive STEM Classrooms

Private and public policies are increasingly aimed at broadening participation of a diverse body of students in higher education, and STEM in particular. As colleges and universities increase compositional diversity, they must also ensure that they cultivate intellectual and social environments where all students have the opportunity to achieve academic success. Positive classroom climates and teaching practices can improve academic and emotional development, as well as persistence, among diverse college students interested STEM fields. However, there is a paucity of meaningful faculty professional development surrounding our personal roles in creating inclusive classrooms. We designed a workshop for graduate students, postdocs, and faculty focused on inclusive excellence in the STEM classroom. The focus of the workshop was on faculty privilege, implicit bias, and cues for stereotype threat that we all bring to the classroom. The workshop included activities related to examining our own privileges and unconscious biases as instructors, and how they may influence our course design and interactions with students. We also presented data regarding stereotype threat interventions, growth mindset, and other approaches that increase student performance and retention in the sciences. Finally, we provided time for participants to engage in guided group work to brainstorm changes related to their course design (e.g. office hours, grading criteria, number/types of assignments) and classroom culture (e.g. nature of in-class activities and student-student interactions). The workshop was interactive and participants left with implementable strategies and increased awareness of their responsibilities as instructors. We feel that this workshop could serve the needs of many STEM departments and career development programs for faculty seeking to broaden participation in their fields.

P2.152 KILVITIS, HJ; HANSON, HE*; THIAM, M; ARDIA, DR; MARTIN, LB; Univ. of South Florida, Université Cheikh Anta Diop, Dakar, Senegal, Franklin and Marshall College; *haleyhanson@mail.usf.edu*

Behavioral Variation in Response and Habituation to Novelty Among Range Expanding House Sparrows in Senegal

Traits such as response to novelty, exploratory disposition, innovativeness, and other behaviors have impacted the success of range expansions.For example, house sparrows (*Passer domesticus*) in Kenya—the site of one of the most recent range expansions of this species—differed behaviorally depending on where they occur within the new range: individuals at the range-edge were less neophobic and more exploratory than individuals residing near the site of introduction (i.e., the population core). Here, we investigated whether these patterns were general among sparrow invasions by measuring behavior in birds from a more recent and independent range expansion in Senegal. We also asked whether birds habituated at different rates to novel environments and objects, something we had not evaluated before in Kenya. We hypothesized that populations near the range-edge would be more exploratory and less neophobic than populations near the site of introduction; we also expected faster habituation in both contexts in range-edge birds. We found that birds closer to the range edge were more exploratory and less neophobic than birds from the core. However, these differences dissipated over time, suggesting that plasticity in these behaviors might underlie the success of this species generally as an invader.

P3.37 KIM, A*; GOSLINER, T; Las Positas College, Livermore CA, Department of Invertebrate Zoology and Geology, California Academy of Sciences; *ashleykim2470@gmail.com*

Stirring up the muck: The systematics of soft-sediment Fionidae (Nudibranchia: Aeolidina) from the tropical Indo-Pacific

Tropical Indo-Pacific aeolidid nudibranchs of the family Fionidae are poorly known. Many undescribed species are found throughout the Indian and Pacific Oceans and are concentrated in the "Coral Triangle", which includes the Philippines, Papua New Guinea, Indonesia, and Malaysia. It has the highest concentration of marine biodiversity for most groups of organisms. With recent publication of revised systematics of the Fionidae, description of new taxa of Fionidae is especially warranted. Interestingly, one particular species, *Tenellia yamasui* Hamatani, 1993, has been repeatedly misidentified. In this project, the phylogenetic placement of *Tenellia yamasui*, *Tenellia* n. sp. 1, *Tenellia* n. sp. 2, *Tenellia* sp. 3, *Abronica* sp. 1 and *Abronica* sp. 2 from the waters inside the Coral Triangle was investigated. Both morphology and molecular data were used to analyze species. SEM photographs of the radula, jaws, and reproductive system were employed to characterize the taxa. DNA was extracted from the foot of the nudibranchs and PCR amplicons were sequenced for mitochondrial 16S, COI and nuclear H3 genes. The newly acquired data were used to complement already existing data in a new, comprehensive phylogenetic analysis. This analysis corroborates the distinctiveness of *Tenellia yamasui* from *Tenellia* sp. 1 and T. sp. 2, with strong support and that these three are each other's closest relatives. This study also confirms that all four species of *Abronica* are characterized by having an acutely-pointed curved penial stylet, thus confirming a unique morphological synapomorphy for members of this genus. It also confirms that *Tenellia* sp. 3 is closely related to coral-eating species of *Tenellia*.

37.3 KIMMITT, A.A.*; DIETZ, S.L.; REICHARD, D.G.; KETTERSON, E.D.; Indiana University, Bloomington, Florida State University, Ohio Wesleyan University; *akimmitt@indiana.edu*

Male mate preference may reinforce population divergence in seasonally sympatric species

In seasonally sympatric species, migratory and sedentary (resident) populations may exhibit overlapping distributions in winter and early spring but become allopatric when breeding. In this case, choosing a mate that exhibits similar reproductive timing may be critical, especially for residents. While males are typically less choosy than females, resident males that are selective in allocating courtship may benefit. In the dark-eyed junco, a species that exhibits seasonal sympatry, we predicted that resident males would exhibit a preference for resident females over migrant females. We tested this prediction by conducting simulated courtship interactions (SCIs), in which we presented a free-living male with a live, female lure (migrant or resident), paired with a population-specific pre-copulatory trill. We then recorded all of the male's courtship behaviors. Trials were conducted 22 May-16 July in 2014 (peak breeding season), and 19 April-13 May in 2016 (early breeding season). Males exhibited no preference for either female type during peak breeding season. However, early in the breeding season, when presented with resident females, males sang more short-range song, a song highly associated with overall courtship effort, approached more closely, and exhibited more visual displays than when presented with migratory females. We conclude that males distinguish between migrants and residents but only early in the breeding season, when risk of interacting with a non-reproductive migrant is high. Males may be less choosy when migrants are no longer present and a cost of choosiness could be the loss of a potential extra-pair copulation.

P1.157 KING, E.E.*; ALAURENT, T; FAY, S.A.; HENDRICKSON, C.; GAPUZ, J.; STILLMAN, J.H.; Univ. of California, Berkeley; *emily_king@berkeley.edu*

Current Conditions Cause Stress for Some Aquatic Caddisflies in the Face of Drought and Warming

Warming global temperatures, barriers to stream flow, and prolonged drought are contributing to rising temperatures in California's aquatic environments. Organisms in these warming habitats may experience physiological stress differently depending on local adaptation. *Dicosmoecus gilvipes*, an aquatic caddisfly with a long larval duration, inhabits streams with differing thermal profiles. Using the larvae of *D. gilvipes*, we investigated the gene expression response to temperature variation in genetically distinct populations from three streams in California, USA. Individuals from each population were exposed to a control treatment, gradual warming mirroring the current stream temperature or a heat shock. We measured normalized expression of nine biomarkers for cellular stress with NanoString technology. We hypothesized that there would be differences in gene expression between treatments in response to thermal stress and between sites due to local adaptation. The treatment significantly affected the expression of five of nine target genes. Those genes, including heat shock proteins, increased their expression with temperature, up to a 14-fold increase at one site. Six of the nine target genes showed significant differences in expression, up to 6-fold, between sites providing some evidence of genetic adaptation to local environmental conditions. All three populations were responsive to thermal stress, though individuals from the warmest site may already experience stress under current conditions that are likely to warm even further with continued warming and drought.

31.1 KINGSOLVER, J.G.*; SHAW, F.H.; Univ of North Carolina, Chapel Hill, Hamline U; *jgking@bio.unc.edu*

Inconstancy is informative: Estimating performance curves in fluctuating environments

Thermal performance curves (TPCs) are widely used to predict mean and variation in performance for fluctuating weather and climate conditions. TPCs are typically estimated by measuring performance at a series of constant temperatures, but these curves sometimes yield poor predictions in fluctuating conditions. We develop a new statistical method for estimating TPCs in fluctuating conditions. The method assumes that there is an underlying TPC function, and uses maximum likelihood to estimate the parameters of this function from data on mean performance of individuals and the temperatures experienced by those individuals. We apply the model to data for mean growth rate of *Manduca sexta* larvae from two sets of experiments, in deterministically or stochastically fluctuating thermal regimes. The estimated TPCs are similar to those estimated from data at constant temperatures over short (4-24h) time scales. Surprisingly, TPCs can be estimated from data based on only 1-2 thermal regimes if they include a wide range of temperatures; and stochastic fluctuations can provide more information than deterministic fluctuations for estimating TPCs. The method is applicable to both experimental and observational (including field) data.

95.2 KINGSTON, ACN*; SPEISER, DI; University of South Carolina; *acnahm@gmail.com*

Diverse sensory structures in the shell plates of chitons express the molecular components of rhabdomeric phototransduction

An important question in integrative biology is how and why complex structures, such as eyes, evolve. Chitons (Mollusca: Polyplacophora) provide a compelling system in which to study eye evolution, as extant taxa display a diversity of sensory structures embedded in their eight overlapping shell plates. These structures can include non-pigmented clusters of sensory cells (aesthetes), modified aesthetes that contain clusters of pigmented sensory cells (eyespots), and extrapigmented aesthetes that integrate an image-forming lens (eyes). Aesthetes are conserved among chitons. In addition to aesthetes, some chiton species have evolved eyespots or eyes. Here, we compare the expression of several molecular components of phototransduction in three species of chiton that represent each character state: *Chaetopleura apiculata*, a chiton with aesthetes, *Chiton tuberculatus*, a chiton with aesthetes and eyespots, and *Acanthopleura granulata*, a chiton with aesthetes and eyes. The aesthetes of each species express a diverse suite of G-protein alpha subunits, including Giα, Goα, Gqα, and Gsα. Aesthetes in each species also express rhabdomeric opsin (r-opsin) and transient receptor potential channel (TRP) proteins. Additionally, photoreceptor cells in the eyespots of *C. tuberculatus* express r-opsin, Goα, Gqα, and Gsα, and photoreceptor cells in the eyes of *A. granulata* express r-opsin, Gqα, and Gsα. Thus, we find that aesthetes, eyespots, and eyes express key components of rhabdomeric phototransduction, suggesting that these structures may detect light using this pathway. The expression of Giα, Goα, and Gsα in the aesthetes may indicate the presence of additional phototransduction pathways or the capability for multimodal sensory detection.

P3.222 KINSEY, CT*; MCBRAYER, LD; Georgia Southern University; *ck03480@georgiasouthern.edu*

The Effect of Obstacles and Forelimb Positions on Bipedal Locomotion in Lizards

Bipedal locomotion has evolved independently in numerous lizard taxa (Clemente, 2014). Initial acceleration, trunk angle, and the posterior shift of the center of mass contribute significantly to bipedal running (Aerts et al., 2003). Recent work indicates that bipedal posture is advantageous during obstacle negotiation. However, the effects of neither obstacle placement, nor forelimb position, have yet to be studied in the context of bipedal locomotion. This study quantified the frequency of bipedalism when running with vs. without an obstacle at 0.8 meters from initiating a sprint. Whether bipedal posture is used at the start of a sprint vs. in the stride preceding the obstacle was also quantified. Additionally, forelimb position during bipedal running and obstacle negotiation will be examined. Two species with contrasting body forms were selected (*Sceloporus woodi*, *Aspidoscelis sexlineata*) to assess potential variation in behavioral patterns. Lizards were coerced to run along a 1.4-meter track and filmed with high speed video. *Sceloporus woodi* ran bipedally at the start of the trial in 77.78% of the trials, regardless of obstacle presence. In the strides approaching an obstacle *S. woodi* ran bipedally in 72.73% of trials. *Aspidoscelis sexlineata* ran bipedally at the start of a trial in 50% of trials regardless of obstacle presence. In strides just prior to the obstacle, *A. sexlineata* ran bipedally in all trials. Data examining forelimb position during bipedal strides will test how forelimb position affects the center of mass and if it may be an applied strategy for navigating obstacles.

P3.140 KIPKETER, AK; GITUKU, BC; WAIGWA, CM; KIPKERING1, PS; NG'WENO, CC; WETZEL, G*; COLLINS, E; SCHREIBER, AM; Ol Pejeta Conservancy, Kenya, St Lawrence University, NY; *aschreiber@stlawu.edu*

Cattle for Conservation: Bomas for Improved Savannah Ecosystems

Ol Pejeta Conservancy (OPC) in Kenya practices an integrated land management system where wildlife and cattle graze together. We hypothesize that abandoned ‘bomas' (temporary enclosures that protect cattle from predators at night) enrich the area with accumulated dung, promoting growth of nutritious grass species that attract wildlife. Three abandoned boma and control sites were studied. Measurements included: biomass (pasture disc meter), grass species composition (pin drops), and dung identification and count to establish which animals use the sites. With the exception of the Eastern sector, which showed no difference, other sectors had 38-52% less biomass in abandoned bomas than controls, suggesting more grazing takes place in the boma sites. Also with the exception of the Eastern sector, the number of pin drop hits for ‘decreaser' grass species (preferred by grazers due to high nutritional content) was 79-85% less in bomas than controls, indicating these species are being consumed preferentially. In contrast, the number of pin drop hits for ‘increaser II' grass species (dominate overgrazed rangelands) was 60-64% higher in bomas than controls. Dung counts of wildlife were generally higher in bomas, with zebras being the exception. Our findings from the Northern and Southern sectors suggest that abandoned bomas attract wild ungulates due to a greater presence of nutritious grasses. The lack of differences in the Eastern sector may be because Eastern OPC is not currently used for ranching, so bomas there are much older than in other areas.

142.5 KIRSCHMAN, L. J.*; QUADE, A. H. ; ZERA, A. J.; WARNE, R. W.; KIRSCHMAN, Lucas; Southern Illinois University, University of Nebraska; *l.j.kirschman@siu.edu*

Immune factor trade-offs in response to parasite threats

Immune function is often involved in physiological trade-offs because of the energetic costs of maintaining the immune system and mounting responses to pathogens. However, immune function is not a single trait, but rather a collection of discrete immune factors. Given limited resources, animals should allocate towards factors that combat the parasite threat with the highest fitness cost. In addition, physiological stress may differentially affect distinct immune factors and allocation priority rules to competing life history demands. In this study, we tested how function of distinct immune factors varies between dispersal phenotypes of a dimorphic cricket and how physiological stress influences allocation to these immunity factors. We measured lysozyme activity, which defends against bacteria and encapsulation, which can destroy parasite eggs. We also stressed the crickets with a sham predator in a full factorial design. Patterns of investment in immune factors could be explained by the major parasite threat likely to be encountered by each morph and was affected by physiological stress. The results suggest that maintaining rapid, constitutive defenses may drive trade-offs between lysozyme activity and encapsulation. Furthermore, the selective pressures exerted by parasites may help maintain dimorphism in some insects via disruptive selection.

P1.216 KISARE, SA*; CRANE, RL; PATEK, SN; Duke Univ., Stanford Univ.; *sak36@duke.edu*

3D printed models reveal morphological features that cue mantis shrimp strike locations

Strategic application of force is often necessary to break open hard-shelled prey and access the food inside. Smashing mantis shrimp (Stomatopoda) break open shells using a series of high impact hammering strikes, yet it is not known which morphological cues they use to target particular regions of the shells. We investigated the morphological features that determine where mantis shrimp strike prey. To do this, we used 3D printed, hollow cylinders to simplify the potential cues present on a real snail shell. Each cylinder had a small hole at one of 3 locations, which was filled with food. We filmed 35 individual mantis shrimp (*Neogonodactylus bredini*) each processing one of the three shapes and analyzed strike locations. We found that despite the presence of food at the variably-placed hole, only 19.7% of the strikes occurred near the hole, whereas 45.9% of the strikes occurred away from the hole (34.4% unresolved locations). Regardless of hole location, on average, 49.4% of the strikes occurred along the rims of the cylinder, 17.4% of the strikes occurred along the cylinder's long axis, and 1.7% of the strikes occurred on the flat faces of the cylinder (31.5% unresolved locations). These results suggest that the rim of the cylinder serves as a morphological cue for mantis shrimp, but that the hole or presence of food may not. This study demonstrates that simple models can be used as tools to uncover the relevant cues and strategies that mantis shrimp and other animals use for strategic processing of hard-shelled prey. This approach has timely potential in this new era of 3D printing capabilities with different materials and shapes.

15.6 KITCHEN, SA*; DEVLIN-DURANTE, MK; HARRIS, RS; RATAN, A; FOGARTY, ND; MILLER, W; BAUMS, IB; Penn State University, University of Virginia School of Medicine, NOVA Southeastern; *sak89@psu.edu*

Genomic evidence of complex hybridization in Caribbean acroprids

Interspecific hybridization plays an important role in adaptive evolution by increasing genomic diversity. Hybridization is common in marine invertebrates, including reef-building corals that externally fertilize gametes. In the Caribbean, hybridization occurs between *Acropora palmata* and *Acropora cervicornis*. Unlike the parental species, the hybrid can occupy non-parental niches, seems to be more thermotolerant and less susceptible to disease. While *A. cervicornis* and *A. palmata* populations continue to decline, recent field observations suggest that the relative abundance of hybrids has increased. However, it remains unclear if this increase in hybrid abundance is the result of asexual fragmentation of existing hybrids, ongoing generation of novel F1 hybids, hybrid mating, or a combination of these mechanisms. In this study, we used 13 microsatellite markers to identify ancestry of hybrids collected in Belize, Curacao, Bahamas and U.S. Virgin Islands. Of these field-identified hybrids, 19% were categorized as complex hybrids resulting from backcrossing of an F1 hybrid with either parental species or second generation hybrids. To better understand the ancestry of these hybrids, we deep-sequenced and assembled the genomes of *A. cervicornis* and *A. palmata* and shallow-sequenced 20 individuals for each species collected from across the species ranges to identify single nucleotide polymorphism (SNP) markers with fixed differences between species. The hybrids were screened using these SNPs and the resulting hybrid ancestry assessment was compared with the microsatellite results. The two novel acroporid genomes not only allow for studies of acroporid genome structure but also help resolve the historical reproduction patterns of the parental species and hybrids.

41.5 KLITTICH, MR*; WILSON, MC; BERNARD, C; RODRIGO, RM; KEITH, AJ; NIEWIAROWSKI, PH; DHINOJWALA, A; University of Akron; *mrk51@zips.uakron.edu*

Too Soft to Stick: Influence of Substrate Modulus on Gecko Adhesion

The gecko adhesion system fascinates biologists and materials scientists alike for its strong, reversible, glue-free, dry adhesion. Geckos encounter a variety of surfaces in their natural habitats; tropical geckos, such as *Gekko gecko*, encounter hard rough tree trunks as well as soft flexible leaves. Gecko adhesion on a wide variety of hard surfaces has been extensively studied, however there has been no work focused on adhesion to soft surfaces. Here, we investigate for the first time the influence of surface modulus on gecko adhesion using two different surfaces (cellulose acetate and polydimethylsiloxane). Understanding the limitations of the gecko system is critical for gecko experimental design as well as for the development of synthetic adhesives, particularly in the biomedical field.

P1.88 KLOMPEN, AM*; ALPERT, EJ; REFT, AJ; ALLEN, JD; College of William and Mary; *amklompen@email.wm.edu*

Do Götte's larvae feed? Culturing indirect developing polyclad flatworms

The feeding capabilities of larval polyclad flatworms are poorly understood. Indirect developing flatworm larvae typically display one of two planktonic larval forms known as Götte's or Muller's larvae. Recent reviews of the literature suggest that Muller's larvae typically develop as obligate feeders, while Götte's larvae are thought to be either non-feeding or facultatively feeding. However, Muller's larvae typically develop from larger eggs (mean ~150 µm) than Götte's larvae (mean ~ 100 µm) and smaller eggs typically reflect lower per offspring investment and greater reliance of larvae on exogenous food. We investigated the feeding requirements of *Stylochus ellipticus*, a polyclad flatworm that develops from a small egg (~65 µm) into a Götte's larva, and whose development has been previously described as non-feeding. Three types of unicellular algae were tested as potential food sources and while all three algae were ingested, only cultures reared on *Rhodomonas lens* developed to metamorphosis. We subsequently tested the effectiveness of three different levels of *R. lens* as a food supply and found that juveniles were only regularly observed when provided algae at high levels (50,000 cells ml^{-1}). These results suggest that the Götte's larvae produced by *S. ellipticus* are obligately feeding. Our observations of development to metamorphosis also confirmed that 4-lobed Götte's larvae do not transform into 8-lobed Muller's larvae as development progressed. Instead we observed that metamorphosis in this species proceeds by the gradual resorption of larval lobes prior to the construction of the juvenile pharynx as well as multiplication of presumptive eye spots. The simple culturing methods described here may be useful in expanding our understanding of the larval biology of polyclad flatworms more generally.

S8.6 KNELL, R.J.; Queen Mary University of London; *r.knell@qmul.ac.uk*

How to build a beetle: larval environment, performance, and sexual signals

Why do male animals with big horns win fights? The link between the expression of the signals used by male animals in contests and the traits which determine success in those contests is poorly understood, and in some cases seems counter-intuitive - for example, in insects which undergo complete metamorphosis such as horned beetles. In these animals signal expression (horn length) is determined during metamorphosis and is fixed during adulthood, whereas performance is influenced by muscles that develop mostly after the animal has emerged as an adult. We used path analysis to investigate the relationships between larval and adult nutrition, horn and body size and fitness-related traits such as strength and testes mass in the horned beetle *Euoniticellus intermedius*. In males weight gain post-eclosion had a central role in determining both testes mass and strength. Weight gain was unaffected by adult nutrition but was strongly correlated with by horn length, itself determined by larval resource availability, indicating strong indirect effects of larval nutrition on the adult beetle's ability to assimilate food and grow tissues. Female strength was predicted by a simple path diagram where strength was determined by eclosion weight, itself determined by larval nutrition: weight gain post-eclosion was not a predictor of strength in this sex. Based on earlier findings we discuss the insulin-like signalling pathway as a possible mechanism by which larval nutrition could affect adult weight gain and thence traits such as strength.

S5.9 KNUTIE, S.A.*; WILKINSON, C.L.; KOHL, K.D.; ROHR, J.R.; University of South Florida, Vanderbilt University; *saknutie@gmail.com*

Early-life disruption of host microbiota reduces later-life resistance to infections

Changes in the early-life host microbiota could affect infectious disease risk throughout life if such disruptions during formative years adversely affect the development of the immune system. We tested this hypothesis by manipulating the microbiota of tadpole Cuban tree frogs (*Osteopilus septentrionalis*) and challenging them with parasitic gut worms (*Aplectana* sp.) later in life. Adult frogs with reduced microbial diversity as tadpoles had significantly more worms as adults than adults with unmanipulated microbiota as tadpoles. This was because tadpole bacterial diversity negatively predicted infections and thus positively predicted host resistance in adult frogs. In contrast, adult gut bacterial diversity at the time of parasite exposure was not significantly correlated with host resistance against parasites. Thus, we demonstrate that an early-life disruption of the microbiota has lasting effects on infectious disease risk, which was likely mediated by its effects on immune system development. Environmental factors that disrupt the early life frog microbiota will also be discussed.

64.8 KO, Y*; PENDAR, H; SOCHA, JJ; Virginia Tech; *yudiko@vt.edu*

Kinematic analysis of gut movements in the beetle Zophobas morio reveals linkages to circulation and respiration

The alimentary canal of insects is a large, continuous tube running from the mouth to the anus, loosely connected to other internal organs via tracheal tubes. Dynamical movements of this organ can affect the surrounding tissues and fluids, but mechanics of such movements have not been well studied. Peristalsis has been suggested to influence hemolymph flow and respiratory ventilation, but there is no direct observation of such linkages. In this study, we used synchrotron X-ray imaging, pressure recordings, and videography to simultaneously observe gut motion, hemolymph pressure, and abdominal movements in the tenebrionid beetle *Zophobas morio*. In addition, we determined the three-dimensional morphology of the gut using micro tomography. X-ray imaging of the live beetles revealed that the gut not only exhibits peristaltic motion, but also shows frequent anterior-posterior pulsatory movements. Furthermore, the pulsatory movement of the gut, unlike peristalsis, is correlated with hemolymph pressure pulses (2.79 ± 0.8 kPa), abdominal pumping, and tracheal tube collapse, which occur on average with a frequency of 12 per minute. Our preliminary results show that, during each pulsatory motion of the gut, the volume of the esophagus increases up to 35% in 0.5 seconds. Therefore, this fast expansion of the gut in the thorax may influence multiple physiological systems by altering hemolymph pressure, compressing tracheae, and possibly pumping hemolymph into the appendages. Supported by NSF 1558052.

116.3 KOBIELA, ME*; SNELL-ROOD, EC; University of Minnesota; *kobie003@umn.edu*

Effects of Road Salt on Butterfly Life History and Potential for Adaptation to High Sodium Levels

Sodium is an essential micronutrient that is required for muscle and neural function in animals. Although this element has historically been limited in availability for terrestrial herbivores, humans have greatly increased the amount of available sodium, especially in northern climates where sodium chloride is used to de-ice roads. Previous research, using butterfly larvae as a model, has shown that moderate increases in sodium appear to be beneficial (i.e. they are able to invest more in brain and muscle tissue), but high sodium levels are toxic. However, it is unknown at what sodium concentrations we will see these apparent benefits or toxicities, and how sodium affects other life history traits, such as development time and fecundity. Furthermore, how much genetic variation exists for sodium-dependent traits or survival at toxic sodium levels is also unclear. This knowledge is essential to predict how butterflies may respond to these anthropogenic changes in nutrient levels. As a first step to answer these questions, we reared larvae from over 20 full sibling families of the cabbage white butterfly, *Pieris rapae*, on diets with 6 different concentrations of sodium. We measured survival, development time, adult body size, eye size as a proxy for investment in neural tissue, and amount of protein in flight muscles as a proxy for investment in muscle tissue. From this, we will be able to estimate broad-sense heritability for these traits and the shape of the reaction norm across the different sodium levels. The results of this experiment will show the relationship between sodium concentration and these butterfly traits, and also determine at what levels road salt application may exert selection on roadside feeding butterflies.

37.4 KOCH, RE*; HILL, GE; Auburn University; *rek0005@auburn.edu*

Exploring the role of carotenoid pigments in immune and antioxidant function using carotenoid- and ornament-free birds

Carotenoid-based coloration in bird species has become a classic example of an honest signal of male quality used in female mate assessment; however, the mechanisms linking carotenoid coloration to male immunocompetence and/or oxidative stress maintenance remain contested. The prevailing hypothesis to explain the honesty of carotenoid-based coloration posits that carotenoid pigments are a limited resource that must be differentially allocated either to ornamental coloration or to boosting beneficial physiological processes such that only healthy birds of good condition can afford to produce a high quality ornament. In this study, we use a novel system of canaries (*Serinus canaria*) with knock-out mutations to directly test the importance of carotenoid pigments to immune and antioxidant processes and to search for a "cost" of allocating pigments to ornamentation. During the annual molt—when yellow canaries are actively depositing carotenoids into their feathers—we compared measures of immunocompetence and oxidative stress in canaries with and without circulating carotenoids (carotenoid-rich vs. carotenoid-free birds), and canaries with and without ornamental feather coloration (yellow vs. white canaries). Interestingly, we found no significant differences in antibody production to a novel antigen (a measure of humoral immunity), plasma bacterial killing capacity (innate immunity), or measures of blood-based oxidative damage and antioxidant capacity between canaries with different carotenoid availability or ornamental usage. Our results raise important questions regarding the hypotheses that carotenoid pigments are essential to proper physiological function, and that the honesty of carotenoid coloration is maintained by the costs of allocating the pigments to coloration.

P2.95 KOCH, N*; WILCOXEN, TE; Millikin University, Millikin University ; *nkoch@millikin.edu*

Effects of simulated tadpole tail predation on post-metamorphic performance in Cuban tree frogs (Osteopilus septentrionalis)

Tadpoles have many predators in the wild and are able to escape from them because they have less myotomes in the tip of their tail, which allows the tail to simply tear off. We examined the effects of tail damage in the early tadpole stages on the development of the tadpole and its leaping and swimming abilities after metamorphosis. We obtained 120 Cuban tree frogs, and to simulate predation, we cut off a piece of the top of the tadpole tails in one experimental group, cut off a piece of the bottom of the tadpole tails in the second experimental group, and did not make any cuts to tails of the control group. After tadpoles completed metamorphosis, they were subjected to a swimming endurance test and subsequent measurement of their leaping abilities. We found no significant effect of tail damage as tadpoles on the leaping abilities of frogs after metamorphosis. We also found no significant difference in body size at metamorphosis among our groups. We then wanted to find out if the tadpoles were actually stressed from the tail damage. We replicated the experiment and tested tadpole corticosterone (CORT) levels after completing the cuts. We found significantly elevated CORT levels in tadpoles with a history of tail damage compared to the tadpoles without tail damage. We conclude that the regeneration abilities of the Cuban tree frog tadpoles afford them the opportunity to survive minor predation events and recover with no apparent long-lasting ill effects even though they were physiologically stressed from the damage. These abilities likely contribute to the Cuban tree frogs' success as an invasive species throughout the Florida peninsula.

141.2 KOCH, L*; SHAINER, I; GUREVICH, T; GOTHILF, Y; HOLZMAN, R; Tel Aviv University, Inter-University institute, Ielat; *liatkoch@gmail.com*

Hunger games: The expression of hypothalamic appetite-stimulating neuropeptides, reveals hydrodynamic-induced starvation in a larval fish

Larval fish suffer dramatic mortality in the days following transition to autonomous feeding, with over 90% of larvae being eliminated within a period of a few weeks. Recent work has shown that the hydrodynamic environment experienced by recently-hatched larvae impedes their feeding rates even under high prey densities. To determine whether these low feeding rates result in acute starvation during this "critical period", we quantified the expression of *agrp1* and *npy*, two hypothalamic orexigenic (appetite-stimulating) neuropeptides whose expression increases upon starvation. The expression of both neuropeptides was quantified in *Sparus aurata* larvae throughout early development (8-23 days post-hatching). Localization of the neuropeptides' mRNA by whole-mount in-situ hybridization confirmed that, in S. aurata larvae, they are expressed only in the hypothalamus. Quantification of both neuropeptides mRNA using Real-time PCR revealed that the expression of this gene is elevated in starved S. aurata larvae compared to fed ones. Manipulating the water viscosity to simulate the hydrodynamic conditions during the onset of the critical period led to increased *agrp1* and *npy* expression. These findings suggest that the hydrodynamic constraints on larval feeding lead to the starvation of small larvae, likely reflecting their state in the natural pelagic habitat.

P3.154 KOCH, R*; KELTING, T; MCCUE, MD; HATLE, JD; Univ. of North Florida, Jacksonville, St. Mary's Univ., San Antonio; *jhatle@unf.edu*

Oxidation of cysteine is affected little by life-extending dietary restriction and is much lower than oxidation of the similar amino acid alanine, in lubber grasshoppers

Dietary restriction (DR), reducing feeding without malnutrition, has a life-extending effect in animals, and methionine (met) and cysteine (cys) have a special role. Diets restricted only in met extend lifespan, and animals on DR plus high levels of met and cys lose the benefits of DR. Life-extension via DR is due in part to hydrogen sulfide signaling. Cysteine is a source for hydrogen sulfide production, yet DR increases hydrogen sulfide production. Here we examine how DR affects organismal oxidation rates of ingested cysteine. Because excess cysteine is oxidized through a pathway that does not produce hydrogen sulfide, our hypothesis is that DR will decrease cysteine oxidation. We compare cysteine to equimolar alanine (ala), which is identical in structure save the hydrogen sulfide group. DR slightly increased oxidation of both cys and ala only at 24 h post-feeding, but not from 1-7 h. Moreover, ala consistently was oxidized ~5-fold more than cys (from 2-24 h). Hence, changes in cys oxidation in response to DR were minimal. Reduced reproduction also extends lifespan in many animals, but the mechanism is not known to involve cys. Consistent with this, life-extending ovariectomy (OVX) had no effect on cys oxidation (1-11 h). Ala oxidation was, again, ~5-fold greater than cys oxidation in controls (from 3-7 h). Surprising to us, ala oxidation was repressed upon OVX to the same low rate as cys oxidation. These results suggest that organismal oxidation rates of cys are not altered greatly upon DR or OVX, but that oxidation rates of cys may be low relative to other amino acids also oxidized via pyruvate.

P2.218 KOCH, R.W.*; SHANNON, R.P.; GUSTAFSON, K.D.; BOLEK, M.G.; Oklahoma State University; *ryan.koch@okstate.edu*

Prevalence and Distribution of a Neoechinorhynchus sp. (Phylum: Acanthocephala) Infecting a New Snail Host (Helisoma trivolvis) in the Great Plains

As adults, acanthocephalans are parasites of vertebrate hosts but use arthropods as intermediate hosts. Some species of acanthocephalans use an additional paratenic host in the life cycle, usually a vertebrate host, where juvenile acanthocephalans survive without further development. However, freshwater snails have occasionally been reported as paratenic hosts for acanthocephalans (*Neoechinorhynchus* spp.) which infect freshwater turtles as definitive hosts and ostracods as intermediate hosts. In a snail survey from 9 locations in Stillwater, Oklahoma, we found juvenile *Neoechinorhynchus* sp. infecting the freshwater snail (*Helisoma trivolvis*). Prevalence ranged from 0% to 70%, depending on the location sampled. To identify this acanthocephalan to species, we amplified 1600 base pairs of the 18S rRNA gene and compared this sequence to an adult acanthocephalan recovered from a red-eared slider turtle. These sequences were genetically identical (100% base pair match). These results indicate that *H. trivolvis* is a new snail host for *N. emydis*. More importantly, the size of juveniles from snails in this study indicates that they are much larger than previous reports of *Neoechinorhynchus* spp. from ostracods, suggesting that worms grow in snail hosts which has important implications on survival as adults in final turtle hosts. Finally, of the 72 *Neoechinorhynchus* sp. recovered from snail hosts, 60% were encysted in the foot of snails, whereas 40% were attached with their proboscis on the mantle collar under the shell. These attached individuals had characteristics similar to adult worms recovered from turtles, suggesting that they are using snails as definitive hosts.

18.4 KOCOT, KM*; STRUCK, TH; MERKEL, J; WAITS, DS; TODT, C; BRANNOCK, PM; WEESE, DA; CANNON, JT; MOROZ, LL; LIEB, B; HALANYCH, KM; Univ. of Alabama, Univ. of Oslo, Johannes Gutenberg Univ., Auburn Univ., Univ. Museum of Bergen, Georgia College and State University, Naturhistoriska Riksmuseet Stockholm, Whitney Laboratory for Marine Bioscience, Johannes Gutenberg University, Institute of Zoology; *kmkocot@ua.edu*

Phylogenomics of Lophotrochozoa with Consideration of Systematic Error

Phylogenomic studies have improved understanding of deep metazoan phylogeny and show promise for resolving incongruences among analyses based on limited numbers of loci. One region of the animal tree that has been especially difficult to resolve, even with phylogenomic approaches, is relationships within Lophotrochozoa. Here, we investigated why lophotrochozoan phylogeny has been such a difficult question to answer by identifying and reducing sources of systematic error. We supplemented existing data with 32 new transcriptomes spanning the diversity of Lophotrochozoa and constructed a new set of Lophotrochozoa-specific core orthologs. In order to reduce possible sources of systematic error, we calculated branch-length heterogeneity, evolutionary rate, percent missing data, compositional bias, and saturation for each of 638 orthologous group (OG) analyzed increasingly stricter subsets of only the best OGs for these five variables. Principal component analysis of the values for each factor examined for each OG revealed that compositional heterogeneity and average patristic distance contributed most to the variance observed along the first principal component while branch-length heterogeneity and, to a lesser extent, saturation contributed most to the variance observed along the second. Missing data did not strongly contribute to either. Although our analyses do not unambiguously resolve lophotrochozoan phylogeny, we advance the field by reducing the list of viable hypotheses. Moreover, our systematic approach for dissection of phylogenomic data can be applied to explore sources of incongruence and poor support in any phylogenomic dataset.

60.3 KOEHL, MAR*; MURPHY, E; HADFIELD, MG; Univ. of California, Berkeley, Univ. of Virginia, Univ. of Hawaii; *cnidaria@berkeley.edu*

Effects of Algal Overgrowth on Water Flow Into and Out of Coral Reefs

Flowing water carries nutrients, oxygen, and prey to the organisms living in coral reefs, carries away wastes and sediments, disperses chemical cues, and transports released larvae from and settling larvae into reefs. Many coral reefs are being overgrown by algae. We studied how algae with different morphologies (branching vs. mat-forming) affected the flow of water into and out of the spaces within Hawaiian reefs dominated by branching coral. Transects across reefs since 2003 showed dominance in different years by living or dead coral, mat-forming bubble algae, or branching algae. Measurements of vertical water velocities into and out of reefs revealed that there was net flow into reefs in concave areas and net flow up out of reefs at convex areas when coral or branching algae dominated, but that flow was stopped when the cover of bubble algae was >60%. Field releases of larval mimics showed that fewer mimics contacted surfaces within reefs (where hydrodynamic forces on larvae are low enough that they can recruit) when there was algal cover, and that bubble algae stopped more mimics from entering the reef than did branching algae. Thus, algae not only compete with coral, but also can interfere with the recruitment of larvae and the transport of materials to and from the organisms living in the reef.

S5.2 KOHL, K.D.*; BROOKS, A.W.; BRUCKER, R.M.; VAN OPSTAL, E.; BORDENSTEIN, S.R.; Vanderbilt Univ., Harvard Univ.; *kevin.d.kohl@gmail.com*

Phylosymbiosis: An Eco-Evolutionary Framework for Relationships and Functional Effects of Microbial Communities across Hosts

Phylosymbiosis describes the eco-evolutionary pattern whereby the similarities of host-associated microbial communities parallel the phylogeny of related host species. A number of studies have failed to uncover this pattern in animal groups in nature. However, we show that under highly controlled conditions, phylosymbiosis is a prevalent phenomenon to varying degrees across animal groups (*Peromyscus* mice, *Drosophila* flies, mosquitoes, *Nasonia* wasps). Specifically, intraspecific microbiota variation is consistently less than interspecific microbiota variation, and topological analyses of each group's complete phylogeny and microbiota dendrogram reveal significant congruence. One could hypothesize that host-specific microbial communities should confer functional benefits to their hosts, while mismatching between hosts and microbes would result in decreased performance. We demonstrate this principle by conducting experimental transplants of autochthonous (intraspecific) versus allochthonous (interspecific) microbiota among closely related wasp species and more divergent mice species. Transplants across wasp species yielded reductions in host survival, and transplants across mouse species resulted in decreased digestive performance. Overall these findings indicate that the composition and functional effects of an animal's microbial community can be closely allied with host evolution, even across wide-ranging timescales and diverse animal systems reared under controlled conditions. We will discuss the potential mechanisms driving observed patterns of phylosymbiosis and avenues for future research.

P2.198 KOKESH, BS*; ANDERSON, LC; ENGEL, AS; South Dakota School of Mines and Technology, University of Tennessee; *Broc.Kokesh@mines.sdsmt.edu*

Assessing the Diversity of Lucinid Bivalves from Coastal and Anchialine Habitats on San Salvador Island, The Bahamas

Lucinids are a diverse group of bivalves and are particularly prevalent members of infaunal seagrass communities, contributing to local biogeochemical cycling by regulating sediment sulfide concentrations. On San Salvador Island in the Bahamas, lucinids have also been reported to inhabit anchialine lakes. In this study, we report the diversity of lucinids from various marine habitats surrounding San Salvador, as well as from two inland lakes, sampled from 2015-2016. Live and dead lucinids (qualified by retaining articulation between both valves) recovered from open marine localities include *Clathrolucina costata*, *Codakia orbicularis*, *Ctena orbiculata*, *Divalinga quadrisulcata*, and *Lucina pensylvanica*. Lucinids from inland lakes are only represented by *Ctena orbiculata*, conforming to the reduced diversity of other groups endemic to these lakes. *Ctena orbiculata* and *Clathrolucina costata* were also never found in association with each other, occupying different habitats entirely. Between localities resampled after one year, we found an apparent decrease in abundance for the death assemblage and a reduced diversity among live lucinids at Graham's Harbor on the island's north coast. The occurrence of Hurricane Joaquin between field seasons is one possible explanation that may have increased shell disarticulation or transport. These preliminary observations require further surveys in order to monitor lucinid diversity over time. Furthermore, as many inland lakes on San Salvador have yet to be investigated for lucinids, extending efforts to endemic populations provides a more complete understanding of San Salvador's marine ecology.

4.2 KONOW, N*; TIJS, C; BIEWENER, A. A.; U. Mass. Lowell, Harvard University; *nicolai_konow@uml.edu*

How does Architectural Gearing affect Muscle Function In Vivo?

Architectural gear ratio (AGR), or the ratio of whole muscle versus myofiber contraction speed, is a phenomenon observed in pennate muscles that results from changes in pennation angle as myofibers contract. AGR has been hypothesized to broaden a muscle's ability to contract at varying levels of force and speed: in shortening contractions, a low gear ratio favors force output, whereas a higher gear ratio allows a muscle to reach higher speeds than achieved by its individual myofibers. In lengthening contractions, however, higher (as well as low) gear ratios would reduce the speed of myofiber stretch relative to whole muscle lengthening, possibly preventing injury. Until now, AGR and muscle volumetric shape changes have only been measured in isolated muscle experiments, in which the systematic relationship between muscle AGR and force for shortening contractions has been observed. To address if this relationship persists *in vivo*, we studied the rat medial gastrocnemius muscle and used treadmill locomotion for different gaits (walk, trot, and gallop) and slopes (0°, +20°, -20°) to elicit contractions with different force levels and length trajectories. We measured changes in muscle belly length, and the length of muscle fascicles via fluoromicrometry ($n = 6$). In separate experiments ($n = 3$), we measured muscle activation and force production *in vivo* via electromyography and miniature tendon force transducers, respectively. We found that *in vivo* AGR was lowest (0.9 ± 0.1) during high-force uphill locomotion and highest (2.6 ± 0.4) during low force downhill locomotion. Hence, the AGR-force relationship of the rat MG *in vivo* appears to match that of earlier *in situ* muscle experiments. Our results support the hypothesis that pennate muscles possess a mechanism in the form of variable gearing to broaden their performance during mechanically diverse movements. Funded by NIH AR055648 to A.B.

P1.7 KONTE, RB*; KAPAN, DD; Cleveland Institute of Art, OH , California Academy of Sciences; *beccakonte@gmail.com*

Field Guide to Mosquitoes of Medical Importance in Hawaii

The Hawaiian Islands are home to invasive species of mosquitoes. Several of these species are vectors of diseases that can pose a serious threat to the health of humans and wildlife. In an effort to reduce this threat, we created an illustrated field guide to serve as a resource that the general public can use to understand basic mosquito biology by focusing on the anatomical differences among species. Specifically, this guide depicts the six non-native, biting species of mosquitoes established in Hawaii. The illustrations for the species plates were created after microscopic analysis of specimens from the California Academy of Sciences and review of taxonomic mosquito literature. Each species plate contains an idealized, realistic illustration of the insect that is supplemented by several diagrammatic line drawings that isolate diagnostic characters. By combining idealized illustrations with diagrammatic drawings, we are able to show mosquitoes simultaneously as they occur in nature while breaking down their complex morphology into simpler, more identifiable forms. With this information, the people of Hawaii can take the initiative to identify and document the mosquitoes they encounter. We will share this guide with participants in the citizen science project "Mosquitoes in Hawaii" hosted on the iNaturalist platform (http://www.inaturalist.org/projects/mosquitoes-in-hawaii). Consequently, this guide will help increase awareness and improve the quality of the iNaturalist data. Ultimately, the knowledge of where each species is found will benefit both public and wildlife health by guiding community efforts and vector control professionals toward enacting more concentrated and effective preventative measures.

P2.67 KORNEGAY, B*; CRAMER, J; POHLMANN, D; GOMEZ, F; MARK, L; HALL, C; SIRALIEV-PEREZ, E; WALAVALKAR, NM; SPERLAZZA, MJ; PROKOP, JW; HILL, A; WILLIAMS, DC; Univ. of Richmond, Richmond, Virginia Commonwealth University, Richmond, Univ. of North Carolina, Chapel Hill, Hudson Alpha Institute for Biotechnology, Huntsville; *ahill2@richmond.edu*
Methylation and chromatin remodeling complex from sponges to humans
Epigenetic regulation by DNA methylation is an important mechanism for controlling gene expression throughout vertebrate lineages. The presence, however, and patterns of DNA methylation varies widely among the invertebrates. Invertebrates generally have only a single methyl-cytosine binding domain protein (MBD), that does not always contain appropriate residues for selectively binding methylated DNA. We asked whether or not sponges, one of the earliest branching animals, possess an MBD capable of recognizing methylated DNA and recruiting the associated nucleosome remodeling and deacetylase (NuRD) complex. We found that both marine and freshwater sponges have genes for each of the NuRD core components, including an MBD ortholog (MBD2/3). We confirm the presence of DNA methylation during development of the freshwater sponge, *Ephydatia muelleri*. Methylation coincides with expression of EmMBD2/3 which is expressed at all developmental stages. Furthermore, we show that EmMBD2/3 selectively binds methylated DNA and forms a coiled-coil interaction critical to recruitment of NuRD. Finally, we show that reducing the expression of EmMBD2/3 during *E. muelleri* development leads to abnormalities at the leading edge of sponge growth in the basal pinacoderm. These data support a model in which the MBD2/3 methylation-dependent functional role emerged with the earliest metazoans and has been maintained to varying degrees across animal evolution.

P3.260 KORZENIECKI, N. W. *; CASSIDY, D.P.; WATERS, J.S.; Providence College; *nkorzeni@friars.providence.edu*
Metabolic Dynamics: From Individuals to Whole Colonies
Ants (Hymenoptera: Formicidae), live and behave in functionally integrated social groups that promote the well being of their colony as whole rather than their existence as individuals. Their collective behavior is responsible for the performance of colonies as super-organisms, but relatively little is known about the physiological causes and consequences of these behaviors. By studying the respiratory characteristics of individual ants and whole colonies, we aimed to identify distinct metabolic signatures of eusociality. To measure the ventilation and metabolic dynamics of acorn ants (*Temnothorax curvispinosus*), we conducted flow-through respirometry to detect real-time changes in the concentrations of oxygen and carbon dioxide induced by the metabolism of whole colonies. We tested the hypothesis that whole colonies synchronize individual-level discontinuous gas exchange cycles so that an emergent pattern of cyclic ventilation might be exhibited by colonies. Results from our study are presented including the characteristic amplitude, wavelength, and power spectra of ventilatory gas exchange time series data.

43.4 KRAEMER, AC*; PARENT, CE; KRAEMER, Andrew; University of Idaho, Moscow; *andrew.c.kraemer@gmail.com*
Life on a Sinking Ship: Morphological Diversification Through Island Ontogeny
The General Dynamic Model (GDM) of oceanic island biogeography extends the predictions of MacArthur and Wilson's dynamic equilibrium model of island biogeography by incorporating geological timescales and the effects of island ontogeny on species diversity. Many of the predictions of the GDM have found support in recent studies of volcanic archipelagos, but this work tends to ignore the morphological diversity of these lineages. We use the spectacular radiation of Galápagos endemic land snails of the genus *Naesiotus* to test several GDM predictions of morphological diversity through island ontogeny. In general, we find support for the GDM in the patterns of *Naesiotus* diversity across Galápagos. In particular, species diversity exhibits the characteristic hump-shaped curve through island ontogeny, with middle-age islands containing the greatest species diversity. In contrast, we find that morphological diversity (i.e. the volume of the morphospace occupied by all the species on a given island) continues to increase as islands age. However, the density of island morphospace becomes increasingly depauperate over time, such that species on older islands tend to be more different from one another than species on younger islands. These results are exciting because they support predictions of the GDM for morphological diversity in that older islands, lacking much of the topographical complexity of middle-age islands, are less able to support many ecologically and morphologically similar species. Instead, as islands age, morphologically unique species may be the last to disappear before the islands themselves submerge.

P2.239 KRAJNIAK, KG*; STEINBERG, M; Southern Ill Univ Edwardsville; *kkrajni@siue.edu*
The Effect of Annelid FMRFamide-Related Peptides on the Isolated Clam Heart
FMRFamide-related peptides are found in most animals, however the authentic FMRFamide along with YMRFamides are found in only molluscs and annelid. Annelids also have YVRFamides. Since FMRFamide excites the heart of the clam *Mercenaria mercenaria*, we decided to see if annelid peptides did the same. For this study we used FMRFamide, FVRFamide, YMRFamide, YVRFamide, AYVRFamide and QYVRFamide. Hearts were placed in a tissue bath of artificial seawater. Contractions were recorded with a force transducer and computer as increasing concentrations of peptide were added to the bath. The data were used to construct log concentration response curves for rate and amplitude changes. FMRFamide stimulated rate (threshold 0.1 µM) and amplitude (threshold 1 µM). FVRFamide caused a small rise in amplitude and rate (threshold 1 µM). YMRFamide caused a small rise in amplitude (threshold 1 µM). YVRFamide stimulated rate (threshold 10 µM) and amplitude (threshold 1 µM). AYVRFamide and QYVRFamide inhibited amplitude (threshold 0.1 µM). The order of potency for the tetrapeptides was FMRFamide > FVRFamide > YMRFamide > YVRFamide indicating that the receptor requires phenylalanine in the N-terminal to a greater extent than it needs methionine in the second position for full efficacy. The extended YVRFamides were inhibitory. The addition of either alanine or glutamine to the N-terminal caused the excitatory YVRFamide to become inhibitory suggesting that the receptor cannot bind the pentapeptide and activate the transduction pathway. The inhibition caused by the pentapeptides suggest that the peptides might be acting as an antagonist to the clam receptor by blocking the effects of any FMRFamide that may be released from the cardiac nerves that are still present in the isolated heart.

27.5 KRAMER, G R; STREBY, H M*; PETERSON, S M; LEHMAN, J A; BUEHLER, D A; LARKIN, J L; MCNEIL, D J; WOOD, P B; ANDERSEN, D E; U of Toledo, UC Berkeley, U of Tennessee, USGS; *henrystreby@gmail.com*

Nonbreeding isolation and population-specific migration routes among three populations of Golden-winged Warblers

Golden-winged Warblers are migratory birds experiencing varied regional population trends that are not explained by breeding-grounds factors. No information exists on nonbreeding distributions, migration routes, or timing of migration among populations, and factors outside the breeding period may influence population trends. We tracked annual movements of Golden-winged Warblers from 3 North American breeding locations experiencing varying population trends using geolocators from 2013-2015 to investigate the potential for nonbreeding-site factors to influence breeding populations. We analyzed geolocator data using the template-fit method, which is more accurate than the more commonly used threshold method. Geolocator-marked Golden-winged Warblers exhibited significant isolation among populations during the nonbreeding period and during migration. Golden-winged Warblers from Minnesota, USA migrated to areas in Central America from southern Mexico to central Nicaragua; warblers from Tennessee, USA migrated to areas along the border of northern Colombia and Venezuela; and warblers from Pennsylvania, USA migrated to areas farther east in central Venezuela. Golden-winged Warblers from these three breeding populations exhibited essentially no effective overlap during the nonbreeding period. Fall migration routes around the Gulf of Mexico were population specific, whereas spring migratory routes were more varied and overlapped among populations. Our results reveal nearly complete temporal and geographic isolation among three populations of Golden-winged Warblers throughout the annual cycle resulting in opportunities for population- and site-specific factors to differentially influence populations.

24.1 KRASKURA, K*; NELSON, JA; OUFIERO, CE; Towson University ; *k.kraskura@gmail.com*

Sprint, Fast Start and Prey Capture Performance of Juvenile Striped Bass under Levels of Hypoxia Encountered in Nature.

Annual hypoxia in the Chesapeake Bay has expanded to the point that juvenile striped bass routinely encounter it and thus their Darwinian fitness may depend upon their ability to perform there. Because locomotion that is critical to predator/prey dynamics relies primarily on white muscle, it was thought to be largely unaffected by hypoxia. However, minimal work has been done to investigate anaerobically powered performances under hypoxia. We subjected juvenile striped bass to three performance tests, sprint swimming, escape response, and prey capture, under acute hypoxia (20% AS) and normoxia (>80% AS). We found a significant, repeatable reduction in sprint swimming performance of juvenile striped bass during hypoxia exposure. Preliminary results also show that responsiveness is lower in hypoxia compared to normoxia, while the locomotor parameters of the escape response are only mildly affected. Furthermore, preliminary results suggest that hypoxia influences prey capture dynamics in a manner that varies strongly by individual. Specific kinematics affected by hypoxia will also be reported. Since the energy to fuel these types of locomotion comes from existing ATP and creatine phosphate stores, the altered performance probably reflects malfunction somewhere along the reflex chain leading from detection of external stimuli to the muscle contraction itself. In addition, defects in vision under hypoxia may be involved.

72.5 KRAUSE, J.S.*; PEREZ, J.H.; MEDDLE, S.L.; WINGFIELD , J.C.; Univ. of California, Davis, Univ. of Edinburgh; *jskrause@ucdavis.edu*

The effects of 1, 2, 6 and 24 hours of fasting on hypothalamic-pituitary-adrenal axis function, body condition, and activity of wintering male white-crowned sparrows

Reductions in food resources or an animal's ability to forage can be greatly affected by perturbations of their environment such as weather events. In response to perturbations, animals activate the hypothalamic-pituitary-adrenal (HPA) axis in order to adjust physiology and behavior. The literature often makes the assumption that during weather events food intake declines leading to changes in HPA axis activity, including both basal and stress-induced circulating concentrations of corticosterone. We aimed to understand how varying lengths of fasting (1, 2, 6, and 24 hours), similar to what would be experienced by free-living birds compared to when food was proved ad libitum, affected body condition, locomotor activity, and stress physiology in captive male white-crowned sparrows, *Zonotrichia leucophrys gambelii*. Basal corticosterone concentrations were increased for all fasting durations but were highest in the 6 and 24 hour groups. Stress-induced corticosterone was elevated in the 1 hour group with a trend for the 2 hour group while no other differences were found. Basal corticosterone concentrations were negatively related to both total fat stores and body mass. All groups lost body mass during the fast with the 24 hour group losing the most. Fat stores declined in the 6 and 24 hour groups during the fast while no measureable changes were detected in muscle profile. Regardless of fasting duration, activity was increased over the entire period in which food was removed. Thus, it is likely that changes in food intake in the wild lead to rapid changes in HPA activity, fat stores, and activity.

35.1 KRAYESKY-SELF, S; WATSON, G/M*; University of Louisiana Lafayette; *gmw5722@louisiana.edu*

Sea Anemones Employ Hair Bundle Mechanoreceptors to Target Spirocyst Discharge to Swimming Appendages of Prey

Hair bundle mechanoreceptors located on the surface of anemone tentacles are employed to detect swimming movements of prey. Proper functioning of the hair bundles is inhibited in the presence of streptomycin. We here find that the anemone *Nematostella vectensis* preferentially discharges spirocysts, an adhesive cnida, onto the second antennae of brine shrimp nauplii that swim into contact with tentacles. Based on the relative size of ‘patches' of discharged spirocyst tubules on the surface of the *Artemia*, the preference for discharging spirocysts onto second antennae, the primary swimming appendages of the nauplii, is by a factor of nearly 3 as compared to the telson, the nauplius region that ranks second in area of discharged spirocysts. In the presence of streptomycin, preferential discharge of spirocysts is abolished for the second antenna decreasing to a factor of only 1.08 as compared to the telson. Nevertheless, overall levels of spirocyst discharge are comparable in the presence and absence of streptomycin. Thus, hair bundle mechanoreceptors on tentacles likely participate in targeting discharge of spirocysts onto secondary antennae of nauplii. Streptomycin does not significantly affect swimming of brine shrimp nauplii. In the presence of streptomycin, anemones are less effective predators than they are in the absence of streptomycin. Evidently, hair bundles on tentacles target discharge of spirocysts to the second antennae of nauplii where the spirocyst tubules function to tether the shrimp to the tentacle and to entangle the second antennae such that swimming performance in prey organisms is greatly reduced.

140.6 KRENTZEL, D*; ANGIELCZYK, K; University of Chicago, Field Museum; *dkrentzel@uchicago.edu*

The evolution of novel jaw adductor muscle configurations in rodents: new insights from kangaroo rats and jerboas using DICE CT

Rodent jaw adductor musculature and mandibular mechanics are unique among mammals. In rodents, incisor and molar occlusion are mutually exclusive. Millions of years after the evolution of this unique mandibular system, jaw adductor musculature began to diversify, convergently evolving toward three distinctly different masseter configurations a number of times. Prior work in our lab using 2D lever mechanics modeling across 200 species of rodents has demonstrated that one of these conditions, sciuromorphy, is associated with incisor gnawing adaptions. Hystricomorphy lacks any clear relationship to either gnawing or chewing performance when it exists alone. When hystricomorphy and sciuromorphy are combined, a condition called myomorphy found in 50% of rodent species, both of the novel muscular units of these conditions demonstrate positive covariation with both gnawing and molar chewing performance metrics. However, these relationships are based on comparative data across tens of species in large clades, such as Sciuridae, Ctenohystrica, and Muroidea. Smaller clades that have independently evolved derived masseter configurations are not amendable to this type of comparative analysis, and unfortunately these groups have been neglected in terms of detailed descriptive anatomy. In order to properly model the biomechanics of the adductor musculature in these groups, we've conducted diffusible iodine-based contrast enhanced computed tomography (DICE CT) scanning on kangaroo rats (*Dipodomys*: Heteromyidae) and jerboas (*Jaculus jaculus*: Dipodidae). These taxa have independently evolved sciuromorphy and hystricomorphy, respectively, however, whether their convergent morphologies are identical to the more well known configurations and will share their biomechanics is an open question.

S4.3 KRIEGSFELD, Lance, J*; JENNINGS, Kimberly, J; MANON, Chasles; CHO, Hweyryoung; MASON, Alex, O; KELLER, Matthieu; University of California, Berkeley, USA, Université de Tours, Nouzilly, France, Université de Tours, Nouzilly, France; *kriegsfeld@berkeley.edu*

Seasonal control of reproductive function by two, complementary RFamide peptides

Animals inhabiting temperate and boreal latitudes experience marked seasonal changes in the quality of their environments and maximize reproductive success by phasing breeding activities with the most favorable time of year. Whereas the specific neuroendocrine mechanisms driving seasonal changes in reproductive function vary across species, converging lines of evidence point to a key role for two, complementary RFamide peptides in guiding this seasonal adaptation. Across mammalian species, the ortholog of avian gonadotropin-inhibitory hormone, RFamide-related peptide-3 (RFRP-3), and kisspeptin are pronounced positive and negative regulators of the reproductive axis, respectively. In addition to anticipating environmental change through transduction of photoperiodic information and modifying reproductive state accordingly, RFRP-3 and kisspeptin are also positioned to regulate acute changes in reproductive status should unpredictable conditions manifest throughout the year. This overview will summarize our findings on the role of RFRP-3 and kisspeptin in mammalian seasonal breeding while considering commonalities and disparities that have emerged from broad investigations across reproductively photoperiodic species. In addition, because rodent species process sexually-relevant chemosensory information differentially across the seasons, our more recent studies explore the neuroendocrine mechanisms by which conspecific chemosensory signals are gated by the olfactory network, including the RFRP-3 and kisspeptin systems. Supported by NIH grant HD050470 and the France-Berkeley Fund.

P2.244 KRINOS, AI*; AHEARN, GA; Virginia Polytechnic Institute and State University, University of North Florida; *akrinos@vt.edu*

Effect of pH on uptake of calcium by crustacean gills

The effects of increased proton concentration in seawater, during ocean acidification, is believed to result in the dissociation of calcium from carbonate and subsequent protonation of carbonate into bicarbonate ion, a form that is unable to complex with calcium to retain calcium carbonate shells. This model assumes a constant supply of calcium during the proton-dependent dissociation process. This research project was undertaken to assess whether calcification disruption may occur through a decrease in organismic calcium concentration in low pH water due to possible transport inhibition between H^+ and Ca^{2+} at cellular sites of uptake. Partially purified gill plasma membrane vesicles (PMV) from American lobsters (*Homarus americanus*) were prepared using a tissue homogenization process in hypotonic buffer, followed by centrifugation purification. Vesicle protein content was determined using the Bradford protein assay. ^{45}Ca uptake at 50 µM, 1, 5, and 50 mM, by PMV loaded with a mannitol-based buffer at pH 8, were measured using three external pH conditions (pH 8, 7 and 6) in the same mannitol-based buffer for time periods from 1 to 30 min. ^{45}Ca influx rates by PMV at each of the 4 calcium concentrations were greatest at pH 8 and least at pH 6, suggesting that increased proton concentration inhibited the uptake of calcium. Hyperbolic influx curves, following Michaelis-Menten kinetics, were obtained by plotting ^{45}Ca influx vs. calcium concentration at each pH value. Increased proton concentration reduced ^{45}Ca influx J_{max}, with less effect on K_m, tentatively suggesting either a non-competitive or mixed effect of H^+ on $^{45}Ca^{2+}$ transport. Results of this preliminary study suggest that increased seawater proton concentration may limit the uptake of calcium and thereby contribute to reduce calcification processes.

26.2 KRUPPERT, S*; HORSTMANN, M; WEISS, LC; WITZEL, U; SCHABER, CF; GORB, SN; TOLLRIAN, R; Ruhr-University Bochum, Germany, University of Kiel, Germany; *sebastian.kruppert@rub.de*

Biomechanical properties of a predator induced body armor in the freshwater crustacean Daphnia

The freshwater crustacean *Daphnia* is known for its ability to develop inducible morphological defenses thwarting predators. These defenses are realized in form of morphological shape alterations e.g. "neckteeth" in *D. pulex* and "crests" in *D. longicephala*. Additionally, *D. pulex* was found to develop a sort of body armor, as its bivalved carapace surrounding the body, increases in overall stiffness. We tested whether *D. longicephala* also develops such a body armor, and investigated the structural features explaining increased stiffness in both species. Using electron microscopy, we found that the carapace architecture becomes highly laminated in both species exposed to predators. Using bio-indentation measurements, we found that this highly laminated structure results in the increase in stiffness (e-modulus). Likewise, we tested whether the overall adaptive morphology results in an increase in geometric stiffness i.e. the extent to which a geometric body resists deformation in response to an applied force. Subsequently, we conducted finite-element analysis considering e-modules as well as carapace architecture and shape alterations to determine whether both factor act synergistically to increase stiffness. We found that increased geometric stiffness is based on the highly laminated carapace. Furthermore, our results revealed species specific structure alterations indicating different, predator specific strategies to realize stiffness increase.

68.2 KUCERA, AC*; WESTNEAT, DF; HEIDINGER, BJ; North Dakota State University, University of Kentucky; *aurelia.kucera@ndsu.edu*

Telomere dynamics and lifetime fitness: a longitudinal study in free-living house sparrows

Understanding the mechanisms that contribute to variation in lifespan is of central importance to diverse fields including life history theory. Mechanistically, lifespan may be influenced by telomere dynamics (length and loss rate). Telomeres are highly conserved, repetitive, non-coding sequences of DNA that enhance genome stability, but shorten during cell division and in response to stress. Telomere dynamics predict longevity within diverse species including humans and birds. Individuals with longer telomeres and/or slower telomere attrition tend to live longer. However, longevity is only one part of biological fitness; how telomere length and loss rate might influence reproductive performance is currently unknown. We used archived data and blood samples collected from 230 free-living house sparrows (*Passer domesticus*) to relate telomere length and loss rate to several fitness components, including longevity and measures of reproductive success. This longitudinal approach is both novel and necessary for understanding how telomere dynamics influences fitness in wild populations. The results will be discussed in the context of life history theory.

49.6 KUHN, AA*; DARNELL, MZ; School of Ocean Science and Technology, The University of Southern Mississippi; *abigail.kuhn@usm.edu*

Long-term effects of temperature on growth and maturation rates in blue crabs (Callinectes sapidus)

Environmental conditions can strongly influence growth rates and size at maturity in ectotherms. For commercially harvested species, understanding these environmental effects is necessary for successful management and stock assessment, especially under changing environmental conditions. Previous laboratory and field experiments suggest that temperature affects both intermolt period (IMP) and growth per molt (GPM) in blue crabs. Field surveys suggest that blue crabs reach maturity at larger sizes in cooler areas, and at smaller sizes in warm areas. We investigated the effects of temperature on IMP and GPM in a laboratory experiment. Crabs were collected as megalopae and held in temperature-controlled environmental chambers at two temperatures: ambient water temperature and ambient + 5°C. Ambient water temperatures were based on water temperatures at the collection site. Crabs were fed daily, checked daily for molting, and measured following each molt. Temperature significantly affected both IMP and GPM. Crabs reared at the warmer temperature molted more frequently but grew less at each molt. At a given age (time since metamorphosis), the crabs in the ambient + 5°C treatment were larger, but if compared within a given stage, the ambient treatment crabs were larger. These results suggest that temperature has a significant role in determining growth rates, which may result in temperature-driven shifts in time to maturation and size at maturity. To directly examine these potential effects on a longer time scale, this study will be extended until all crabs reach maturity.

P1.229 KUHN-HENDRICKS, SM*; ERICKSON, GM; NORELL, MA; Florida State University, American Museum of Natural History; *sh12f@my.fsu.edu*

Enamel Microstructural Changes in Equids Conferred Damage Tolerance Through Controlled Fracture and Damage Localization

The morphological modifications that equid ungulates underwent during the Miocene climatic and floral changes represent a classic evolutionary story. During their radiation they showed increases in cursoriality, body size, hypsodonty, and occlusal enamel complexity. Enamel microstructure changes accompanied the dental modifications. Browser-frugivore *Hyracotherium* displays primitive horizontal Hunter-Schreger bands (HSB). The cladogenesis of *Parahippus*-grade mixed-feeding horses show derived modified radial enamel (MRE), a microstructure retained in subsequent lineages. The changes in diets led to greater ingestion of small, hard particulates in grazers and body size increases that promoted enamel degradation. We posit that MRE evolved to counter these wear and fracture promoting agents. Sampling from nine equid genera, we use instrumented Vicker's microindentation to determine hardness and promote controlled fracture to study crack channeling. Hardness measurements show a gradient across the enamel, with increased hardness toward the outer enamel. However, there is no clear trend of increased hardness across taxa. On the other hand, we find evidence of increased crack channeling within the MRE. Perfuse indentation fracture follows intersprismatic rows and travels normal to the enamel-dentine junction. Fracture path in the HSB mid-enamel displays a bimodal distribution as cracks are channeled along prism boundaries. Outer radial enamel exhibits a reduced degree of fracture control. Results were further corroborated by neontologic data. MRE is a wear and fracture resistant microstructure that inhibits enamel damage by localizing damage and preventing microcrack coalescence that evolved in equids in response to dietary and loading changes. The development of biologically-inspired ceramics may result.

P3.77 KUMRO, MB*; STRAND, CR; Cal Poly State Univ, San Luis Obispo; *cstrand@calpoly.edu*

Sex differences in cortical brain region volumes in Western fence lizards, Sceloporus occidentalis

The dorsal and medial cortices (DC and MC) are hippocampal homologues in reptiles. These regions exhibit plasticity in response to changes in spatial navigation. For example, in side-blotched lizards, territorial males have larger DC volumes than non-territorial males. However, little is known about differences between males and females. In *Sceloporus occidentalis*, males have larger territory sizes than females. Given this, we expected males to have larger MC and/or DC volumes than females. However, previous work in our lab on captive lizards indicated that females have larger MC volumes than males. To determine if the sex differences we found in MC volume resulted from the conditions in our captive experiment or if they represent free-ranging animals, male and female *S. occidentalis* were captured from the wild during the breeding season and during the post-breeding season and were sacrificed within two days of capture. Brains were collected and processed for histology. Cresyl-violet stained sections were used to quantify brain region volumes. In these lizards, females had larger DC volumes than males but there was no sex difference in MC volumes. These sex differences may be related to differences in spatial navigation in these populations of lizards that may involve aspects of spatial memory other than territoriality. Future work will address behavioral differences in space use or territory size that may be related to these unexpected sex differences in cortical volumes.

16.7 KUO, C-Y*; RUTA, A; THOMPSON, C; PATEK, SN; Duke University, Charles E. Jordan High School; *ck188@duke.edu*

Extreme asymmetry in the energy transfer rate of trap-jaw ant mandibles

Extremely high speeds and accelerations are achieved through power amplification: a class of mechanisms that reduce the duration over which work is performed. Animals contract slow, forceful muscles to store elastic potential energy in springs and then suddenly release potential energy through latch or catch mechanisms, which act as the critical barrier between the slow accumulation of potential energy and the rapid transduction to kinetic energy. Such asymmetry in energy flow and resultant power amplification is typically inferred, rather than measured, due to the challenges of measuring these movements at exceedingly short time scales. Therefore, a fundamental understanding of latching dynamics is still needed in order to fully incorporate the asymmetric energy flow of energy storage and release into the mechanisms of power amplification. We measured the timing of energy storage and latch release in the trap-jaw ant *Odontomachus brunneus*, which uses power-amplified mandible strikes for prey capture and escape jumps. Using high-speed videography (up to 300,000 frames/sec), we measured the duration of energy storage and captured the fleeting process of latch release in *O. brunneus* (energy storage: 8 ants; latch release: 11 ants; head length: 2.01-2.83 mm). Coupled with existing data on the duration of mandible strikes, we found that the temporal scales of the three stages spanned four orders of magnitude (energy storage: 10^{-1} s; latch release: 10^{-5} s; mandible strikes: 10^{-4} s). We also observed variation in the duration of energy storage and latch release both within and among individuals, although how this variation translates to variable kinematic output remains to be tested. These results highlight the extreme temporal asymmetries of energy flow and the critical role of latch release for fast, power-amplified movements.

87.5 KURNATH, P*; BEALE, P; MARSH, KJ; FOLEY, WJ; DEARING, MD; Univ. of Utah, Australian National University; *patrice.kurnath@utah.edu*

A Tale of Temperature and Toxins: Investigating the Mechanism of Temperature-Dependent Toxicity in Mammalian Herbviores

Intrinsic factors such as plant toxins and nutrients are well known to influence diet selection in mammalian herbivores, yet extrinsic factors like ambient temperature have received less attention. Growing evidence suggests that dietary plant toxins become more toxic at warmer ambient temperatures. This phenomenon, known as temperature-dependent toxicity (TDT), could have serious implications for mammalian herbivores that must balance homeothermy with xenobiotic metabolism in a warming environment. Here, we explored TDT in two distantly related mammalian herbivores, the desert woodrat (*Neotoma lepida*) and the common brushtail possum (*Trichosurus vulpecula*), through investigations of the hepatic response to TDT. We utilized two methods to measure liver function. Hypnotic state assays determined drug clearance times and provided a non-lethal, whole-organism measure of overall liver function, and differential gene expression in the liver was measured with a species-specific microarray. In both herbivores, drug clearance times were significantly longer at warmer temperatures compared to cooler temperatures, indicating a decrease in liver function. In the microarray investigation with *N. lepida*, a greater number and diversity of genes were differentially expressed at 22°C compared to 27°C, providing further evidence that warmer temperatures impede overall liver function. Taken together, our work has identified reduced liver function as a potential mechanism of TDT as well as called attention to the commonality of TDT across mammalian herbivores, regardless of their body size or the dietary plant toxins they face at every meal. These results have also elucidated new challenges that mammalian herbivores may face as global temperature rise.

11.4 KUTCH, IC*; FEDORKA, KM; University of Central Florida; *kutch.bio@knights.ucf.edu*

Does the Y-chromosome facilitate sexual dimorphic evolution or constrain autosomal evolution?

Non-protein coding regions of the Y-chromosome have been shown to influence the expression of hundreds of autosomal and X-linked genes in multiple species. This Y-linked regulatory variation (YRV) may provide the sex-specific variation in gene expression needed for the adaptive evolution of sexually dimorphic traits. Our previous work in *Drosophila melanogaster* suggests that this variation exists where selection operates suggesting that YRV can influence how autosomal traits evolve. In order for YRV to adaptively facilitate the evolution of sexually dimorphic traits, it must be comprised of additive genetic variation. Non-additive Y-linked effects can facilitate or constrain adaptive evolution depending on how these effects translate into genetic variance components at the population level. We investigated the ability for selection to shape immune related YRV by crossing 4 *D. mel* Y-chromosomes into 4 genetic backgrounds, estimating the additive and non-additive effects on response to gram-negative and gram-positive bacteria. Significant Y-linked effects were only detected in response to gram-negative bacteria. Potential reasons for the lack of detection of Y-linked effects in response to gram-positive bacteria are discussed. The Y-linked effect detected in response to gram-negative bacteria was completely epistatic showing no additive effects. This suggests that the potential for YRV to facilitate sexually dimorphic immune evolution via large additive effects that can be shaped by natural selection is small. However, small amounts of additive YRV may exist in the population and we investigate the potential consequences that may arise from large non-additive Y-linked effects on autosomal gene expression ranging from the potential facilitation of adaptive evolution to massive constraints.

P1.93 KYRKOS, J*; LACHANCE, D; CZESNY, B; SANGER, T; Loyola Univ. Chicago; *tsanger@luc.edu*

The Developmental Defects Associated with Thermal Stress in Anolis sagrei

Global climate change is affecting organisms at rates to which they cannot readily adapt. Terrestrial vertebrate ectotherms, squamates in particular, are especially sensitive to these rising temperatures. Some models predict that the Earth will warm beyond the physiological and behavioral buffering capabilities of many squamates within the next 100 years. In spite of these concerns, little research has directly addressed how increasing temperatures will challenge the reproductive output and development of lizards. To address this problem, we performed a series of experiments to address the incidence and nature of structural developmental defects induced by thermal stress in the brown anole, *Anolis sagrei*. We hypothesized that higher incubation temperatures will lead to increased rates of developmental abnormalities and decreased rates of survival. As anticipated, the incidence of structural defects increased with incubation temperatures within the 100 year climate change forecast. Developmental defects were observed across the body, but were concentrated to the head and brain. Embryos exhibited higher survival and less extreme malformation under a short-term, sub-lethal heat shock compared to long-term incubation at elevated temperatures. Our observations suggest that rising temperatures associated with climate change may pose a novel challenge for embryological development of reptilian species that deserves greater attention by the community.

50.3 LADDS, M A*; SLIP, D J; HARCOURT, R G; Marine Predator Research Group, Department of Biological Sciences, Taronga Conservation Society Australia; *monique.ladds@hdr.mq.edu.au*

Intrinsic and Extrinsic Influences on the Metabolic Rates of Three Species of Australian Otariid

The study of marine mammal energetics can shed light on how these animals might adapt to changing environments. Their physiological potential to adapt will be influenced by extrinsic factors, such as temperature, and by intrinsic factors, such as sex and reproduction. We measured the standard metabolic rate (SMR) of males and females of three Australian otariid species (two Australian fur seals, three New Zealand fur seals and seven Australian sea lions). We found that Australian sea lion mass-specific SMR (sSMR ml O_2 min^{-1} kg^{-1}) varied little in response to time of year or moult, but was significantly influenced by sex and water temperature. Similarly, Australian and New Zealand fur seals sSMR was also influenced by sex and water temperature, but as well by time of year (pre-moult, moult or post-moult). For both groups females had higher sSMR than males, but sea lions and fur seals showed different responses to changes in water temperature. Fur seals sSMR increased with increasing water temperature while sea lions sSMR decreased with increasing water temperature. During the moult fur seals had significantly higher sSMR than at other times of the year, while there was no discernible effect of moult for sea lions. There were no species difference when comparing animals of the same sex. Our study suggests that fur seals have more flexibility in their physiology than sea lions, perhaps implying that they will be more resilient in a changing environment.

S8.1 LAILVAUX, SP*; HUSAK, JF; University of New Orleans, University of St Thomas; *slailvaux@gmail.com*

Predicting life-history trade-offs in whole-organism performance

Whole-organism performance traits are key intermediaries between the organism and the environment. Because performance traits are energetically costly to both build and maintain, performance will compete with other life-history traits over a limited pool of acquired energetic resources at any given time, potentially leading to trade-offs in performance expression. Although these trade-offs can have important implications for organismal fitness we currently lack a conceptual framework for predicting both where trade-offs might be expected, and which traits may be especially prone to trade-offs with other fitness-related life-history traits. We propose such a framework based on the energetic requirements of locomotion in vertebrates. By analysing existing data on vertebrate metabolic rates, aerobic capacities, and life-history traits, we test for patterns in energetic profiles that are predictive of key life-history relationships. We also discuss the potential implications of endothermy and ectothermy for masking such relationships, and how this framework might be expanded upon in the future.

13.3 LAINOFF, AJ*; YOUNG, NM; HALLGRÍMSSON, B; MARCUCIO, RS; Univ. of California, San Francisco (UCSF), UCSF, Univ. of Calgary, AB; *alexis.lainoff@ucsf.edu*

Identifying Sources of Craniofacial Phenotypic Variation Produced by Small Changes in Sonic hedgehog (SHH) Signaling

Variation is the key element of biological populations that natural selection works upon to produce evolutionary change. Sonic hedgehog (SHH) signaling variation has been implicated in major evolutionary transformations in craniofacial morphology, including between avians and mammals, and between cavefish populations. In humans, mutations in SHH and in other members of the SHH signaling pathway have been linked to the disease holoprosencephaly (HPE). HPE phenotypes range broadly from mild midfacial narrowing to cyclopia, but it remains unknown what causes this broad range. Our lab has collected data suggesting that the relationship between SHH-signaling and facial morphology appears to be non-linear. We are determining whether modulating the cellular reception of SHH will produce a continuous spectrum of facial phenotypes by producing an allelic series of mouse embryos with discrete, genetic reductions in both the cell's ability to respond to SHH (via loss of functional alleles for the endocytic receptor LRP2) and in the amount of ligand available (via loss of functional SHH alleles). We used geometric morphometric analysis to quantify craniofacial shape variation, and used TUNEL and immunohistochemistry to examine cell death and proliferation, respectively. Our preliminary data indicate that the greatest differences in craniofacial shape exist between SHH+/-; LRP2+/- embryos, and embryos with loss of either a single SHH or LRP2 allele or wild type embryos. Examining how small changes in SHH signaling produce morphological variation will better our understanding of not only human disease, but also of macroevolutionary changes in morphologies dependent on SHH signaling.

P2.21 LAM, E.K.*; GUNDERSON , A.R.; PAGANINI, A.W.; TSUKIMURA, B.; STILLMAN, J.H.; Romberg Tiburon Center, San Francisco State Univ., , California State Univ., Fresno, Romberg Tiburon Center, San Francisco State Univ., Univ. of California, Berkeley; *elam2@mail.sfsu.edu*

Predicting mechanisms that control reproductive fitness under warming by correlating neural physiology and avoidance behavior in the porcelain crab, Petrolisthes cinctipes

Small-scale shifts in population distributions are expected to occur in the intertidal zone under future climate scenarios and may reduce fitness. The intertidal crab, Petrolisthes cinctipes, experiences thermal fluctuations that can reach lethal levels. However, both the extent to which crabs move in response to temperature and the thermal thresholds that trigger migration to cooler microhabitats remain unknown. Escape reflexes, which vary with size and reproductive state, allow organisms to remain within their preferred habitat where they are near their optimal body temperature. Smaller crabs have a higher escape temperature (T_{esc}) (R2=0.39, p<0.01) compared to larger ones. Gravid females have a lower mean T_{esc} (19.6&degC) than non-gravid crabs (22.1&degC). Behavioral responses to changes in temperature may be controlled by thermosensory neuronal systems in the walking legs, as whole organism and neural thermal tolerance are correlated with habitat temperature. We aim to define the thermal thresholds that elicit avoidance behavior, determine variance in populations, and elucidate the mechanical cause by comparing spontaneous action potentials to T_{esc} during stress. The vulnerability of marine organisms to global change is predicated on their ability to utilize and integrate these physiological and behavioral strategies to promote survival and reproductive fitness; understanding these strategies will allow predictions of species distributions under warming and the potential for local extinction.

P3.47 LAMB, A. D.*; NEAR, T. J.; FEDERMAN, S.; DORNBURG, A.; North Carolina State University; North Carolina Museum of Natural Sciences, Yale University, North Carolina Museum of Natural Sciences; *adlamb@ncsu.edu*

Cradles and museums of Antarctic biodiversity

Isolated in one of the most extreme marine environments on earth, the teleost fish fauna of Antarctica's Southern Ocean is dominated by one clade: notothenioids. However, as this region undergoes some of the fastest rates of environmental change, the long-term persistence of this unique fauna is jeopardized. Forecasting the response of these species to contemporary environmental perturbations requires an understanding of how notothenioids have persisted through climatic change events over their evolutionary history. Do shifts in climatic regimes correspond with changes in biogeography or pulses of extinction? Here we use a combination of phylogenetic and biogeographic modeling to infer the biogeographic history of living notothenioid fishes. We show that the High Antarctic represents a biodiversity sink. In contrast, sub-polar regions, specifically the Northern Antarctic Peninsula, have repeatedly acted as source areas for the recolonization of teleost fish biodiversity in the High Antarctic. Contemporary trends of global climate change threaten to invert these evolutionary dynamics of lineage expansion out of the Antarctic Peninsula. Today, this evolutionary refugium and speciation zone is poised to become a main entry point for invasive colonizers, while simultaneously disrupting connectivity between the Southern Ocean's high latitudes and surrounding sub-Antarctic areas.

P1.108 LANCE, SL; RAINWATER, TR; ZAJDEL, J*; WILKINSON, PM; PARROTT, BB; Univ. of Georgia, Clemson Univ., Tom Yawkey Wildlife Center; *lance@srel.uga.edu*

Mating Dynamics and Population Genetics of a Coastal Population of American Alligator

The American alligator (*Alligator mississippiensis*) represents a key species in the coastal Southeast, yet, little is known regarding the mating and nesting dynamics of this species. The Yawkey Wildlife Center (YWC) on the coast of South Carolina represents a unique opportunity to investigate these dynamics. The population of alligators inhabiting the YWC is relatively small, isolated, and has historically remained free of hunting pressures. In addition, long-term capture data characterizing the locations, growth, size, and sex of individuals comprising this population are available. We initially used existing microsatellite markers to examine parentage in 10 nests from 2011. Those markers had been developed and screened for polymorphism from alligators originating in Louisiana. In a sample of 98 adults from YWC the expected and observed heterozygosities were both 0.54 with an average allelic diversity of 5.2. We developed new loci using DNA from a YWC adult and a next generation sequencing approach and identified more than 3000 loci and screened 48 across a subset of YWC adults. Our variation improved with expected and observed heterozyosities increasing to 0.792 and 0.795 respectively. In addition the allelic diversity more than doubled to 11.1. We then screened hatchlings from 38 nests sampled from 2011-2013 and estimated that a minimum of 11% had multiple paternity. The population at YWC may be larger than originally thought given the low number of adults in our genetic database but yet has relatively low genetic diversity. We are expanding the population genetic work to compare multiple barrier island, coastal, and inland populations.

125.1 LANE, SJ*; SHISHIDO, CM; MORAN, AM; TOBALSKE, BW; WOODS, HA; Univ. of Montana, Univ. of Hawai'i, Manoa; *steven.lane@umontana.edu*

Scaling of Respiratory Variables in Cutaneous Gas Exchange by Sea Spiders

Metazoan respiratory systems are diverse, and the size and components of the respiratory system often scale with body size. Many vertebrates rely on gills and lungs for gas exchange, and the surface area and thickness of the respiratory barrier (gill or lung) is the primary limit to oxygen transport. Some organisms and life stages, however, rely on cutaneous gas exchange, which means that the respiratory surface (egg shell, skin, or cuticle) serves two primary functions: gas-exchange and structural support. The respiratory surface must be thin and porous enough to transport gases but strong enough to prevent buckling or tearing from external forces. Here, we tested whether surface area and thickness of the gas-exchange barrier together explain the limits to oxygen uptake in twelve species of sea spiders (pycnogonids); a group of animals that rely on cutaneous respiration. Respiratory surface area scaled with a lower exponent ($b = 0.67$) than that of endothermic and ectothermic vertebrates ($b = 0.89$ and $b = 0.78$, respectively, Gillooly et al., 2016), but cuticle thickness scaled with a higher exponent ($b = 0.3$) than endothermic and ectothermic vertebrate barrier thickness ($b = 0.1$ and $b = -0.04$, respectively). We hypothesize that the difference in scaling exponents reflects the unusual dual role of the sea spider cuticle in both structural support and gas exchange. In further contrast to vertebrates, the scaling of surface area and cuticle thickness in sea spiders did not match the scaling of metabolism ($b = 0.9$). To meet this mismatch, the diffusion coefficient of oxygen in cuticle scaled positively with body size ($b = 0.11$) reflecting that larger sea spiders have thicker but increasingly porous cuticle. NSF PLR- 1341485.

P3.44 LANE, KR*; BENNETT, SN; Macalester College, Saint Paul, MN, California Academy of Sciences; *klane@macalester.edu*

The 2013 Chikungunya Viral Outbreak in Grenada: A Phylogenetic Analysis of Introduction and Spread

Chikungunya virus (CHIKV) is a rapidly re-emerging global pathogen causing both acute and chronic disabling illness. There is currently no vaccine. An RNA virus, CHIKV is transmitted to humans by the mosquito vector *Aedes aegypti* and related species. *A. aegypti* is the same species that transmits Dengue and Zika viruses. Described in 1955, CHIKV existed in two genotypes: West Africa and East, Central, and Southern Africa. Towards the end of the 20th century, CHIKV diversified into a European strain (Indian Ocean Lineage) and an Asian strain that has rapidly spread through Central and South America. This rapid spread has been driven by a) expanding mosquito vector populations as a result of urbanization and climate change and b) increased human global travel. CHIKV was introduced into the Caribbean in 2013, which led to an explosive outbreak in Grenada. Collaborating scientists collected 143 CHIKV samples from acute case symptomatic patients and confirmed positive infection. At the California Academy of Sciences, RNA was extracted from CHIKV positive sera, RNASeq libraries were prepared, and Illumina Miseq sequencing was performed on 12 initial samples. Sequencing reads were parsed, cleaned, and assembled into viral consensus genomes. Phylogenetic analyses were performed using maximum likelihood methods. All of the Grenada samples except for one form a monophyletic group, suggesting a single main introduction of CHIKV into Grenada, as well as a rare importation from Brazil. This reflects human travel among Grenada and other islands in the Caribbean as well as South America. Because viral mutations facilitate emergence and determine disease dynamics, phylogenetic analyses of CHIKV provide a deeper understanding of this pathogen and public health challenges.

2.6 LANG, A. W.*; SLEGERS, N.; WILROY, J. A.; WAHIDI, R.; HEILMAN, M.; CRANFORD, J.; YODER, J.; University of Alabama, George Fox University, University of Alabama Huntsville; *alang@eng.ua.edu*

The Aerodynamic Benefit of Butterfly Scales

Butterfly scales, measuring about 0.1mm in size, cover the wing in a roof shingle pattern and present a means by which the skin friction drag may be altered based on flow orientation over the surface. By strategic placement of the scales on the wing it is hypothesized that an aerodynamic benefit may result. This study carried out an experimental investigation of this effect through flight tests of live Monarch butterflies, as well as simplified fluid dynamic studies on leading edge vortex (LEV) formation. The LEV is the main mechanism for lift production during flapping flight. First, a method was developed to measure butterfly flapping kinematics optically over long uninhibited flight. Using the Autonomous Tracking and Optical Measurement (ATOM) Laboratory located at the University of Alabama Huntsville, 22 Vicon cameras were located at the top of a 5.7m × 9.1m × 3.0m capture volume. This permitted millimeter level tracking of reflective markers placed on freely flying specimens. Results for 11 butterflies (246 flights) both with and without their wing scales showed that the mean climbing efficiency decreased by 37.8% after scales were removed. Also, the flapping amplitude decreased by 6.7% while the flapping frequency was not altered significantly. Next, to better understand the effect the scales may have on flight, their effect on LEV development needs to be understood. Experiments carried out using Digital Particle Image Velocimetry found that altering the fluid friction through butterfly-inspired surface roughness had an effect on vortex growth. The potential impact of this result on induced drag and ultimately flight efficiency for a butterfly will be discussed.

P2.131 LANGAGER, MM*; BRIDGE, ES; ELDERBROCK, EK; SCHOECH, SJ; University of Memphis, University of Oklahoma; *mlangager42@gmail.com*

Effect of sex-specific food supplementation and corticosterone on parental behavior in Florida Scrub-Jays (Aphelocoma coerulescens)

The quality and quantity of parental care can be highly variable among individuals of the same species. Several factors can influence this variation, including local food availability, body condition, and other environmental "stressors". We studied the effect of food availability on parental care by providing live mealworms to either male or female Florida Scrub-Jays via automated feeders (*SmartFeeders*) controlled by radio-frequency identification (RFID) tags. Nest attendance and parental feeding rates were measured using high-definition cameras at supplemented and control nests (when nestlings were 3-5 days post-hatch). During years of male-only supplementation, supplementation had no effect on female or male parental behaviors. However, when females were selectively supplemented, female nest attendance increased, while male parental behavior was unchanged. Further, baseline CORT levels taken in the pre-breeding season (1-2 months before nesting) had no relationship to male feeding rates but females with higher levels of pre-breeding baseline CORT spent less time on the nest than those individuals with lower CORT levels. Supplementing males did not change the relationship between pre-breeding baseline CORT and nest attendance in females; however, this relationship was eliminated in supplemented females. These results suggest that the factors influencing baseline CORT in the pre-breeding season, and high food availability during nesting, affect only female parental behavior. Together this suggests that female parental behavior is more "flexible" and responsive to environmental factors and male parental behavior is more "fixed."

P3.99 LANGE, A P*; YANG, P; MOHAMED, A; ARTEAGA, E; LENT, D D; California State University, Fresno; *alange1@mail.fresnostate.edu*

Hives of the Common Eastern Bumblebee, Bombus impatiens, rapidly alter their foraging patterns based on sudden changes in local flower distribution

Bumblebees are able to obtain information both through personal experience and from their conspecifics, but it is unknown if bees are capable of making the best decision when social information conflicts with personal information. Recent research has suggested that bumblebees are capable of communicating complex information, a prerequisite for decision-making in a social context. Bees were presented with an arena where the values of food resources were controlled by altering the sugar concentration within artificial flowers and the pollen distribution of natural flowers. The foraging patches that bees chose and the subsequent foraging choices the bees made after social information was acquired was monitored to evaluate the transmission of information. The change in behavior provides insight into what drives a bee's foraging choices following new information and provides a framework to investigate how bumblebees evaluate and utilize social information that may conflict with their personal information. In response to changes in floral distribution, bees were found to spend more time on foraging trips to higher quality clusters, as well as visiting said clusters with a higher frequency. While the differences between the two feeders were not always significant, a pattern was clear. The lack of consistent significant changes in feeder visits and changes in trip duration could possibly be explained by the small distances at which the experiment took place.

P2.121 LANGE, EC*; HUGHES, KA; Florida State Univ.; *elange@bio.fsu.edu*

The effects of social environment on male alternative tactics

Understanding the maintenance of phenotypic variation in the face of strong erosive processes (e.g., directional selection and drift) is a paradox in evolutionary biology. Variation in life histories and mating behavior persists in many species, even in the face of strong selection. This discrepancy between theory and nature might be resolved by considering social environment. In group-living species, social interactions can mediate both developmental mechanisms and fitness consequences of phenotypes, thus promoting variation. To examine how social environment might shape the development of life history and mating behavior variation, we used sailfin mollies, *Poecilia latipinna*, a livebearing fish that exhibits extreme variation in male life history and mating behavior. Full siblings (N=5 per treatment per family) were reared from birth in one of five social treatments (1 small male + 2 females, 1 large male + 2 females, 3 adult females, 3 unrelated juveniles, or no non-focal fish). Upon maturation, age, size and mating behavior were recorded for each male. Life history phenotype was affected by social treatment; compared to other treatments, males reared with 3 females took longer to reach maturity ($F_{4,27}$=2.96, p=0.038) and tended to have larger body sizes once mature ($F_{4,27}$=2.36, p=0.080). There was no effect of male social treatment on male mating behavior (gonopodial thrusts: $F_{4,25}$=0.45, p=0.76; courtship displays: $F_{4,25}$=0.15, p=0.96). These results demonstrate that social context shapes male life history phenotype, but not behavior at maturity, and suggest that natural seasonal variation in social environments could maintain the dramatic male life history variation in this species. Mating behavior may be affected by social environment in subsequent mating bouts, a hypothesis is currently being tested.

45.1 LANGKILDE, T*; ROBBINS, TR; DEWITT, G; HOOK, M; JACOBS, A; MCGINLEY, S; Penn State University, Penn State University; University of Nebraska, Omaha; *tll30@psu.edu*

Why does the Mexican Jumping Bean jump?

Mexican Jumping Beans are popular novelty toys, but we have a poor understanding of the adaptive significance of their intriguing jumping behavior. Mexican Jumping Beans are comprised of moth larva (*Laspeyresia saltitans*) contained within the seedpod of a shrub (*Sebastiana pavoniana*). The larva inside the seed is responsible for the beans' jumping motions. We examined avoidance of environments that may cause or indicate risk of overheating or desiccation. We placed beans at one end of arenas containing gradients of heat, light or moisture, and monitored their position for 24 hours. Beans selected cool or dark environments, actively avoiding warm or light environments, but did not respond to substrate moisture. We also documented repeatable variation in individual bean propensity to jump. Jumpier beans were more likely to escape lethally high temperatures, and the ability to jump at all increased survival of beans in the face of high temperatures. These findings suggest that the jumping behavior of the larvae contained in Mexican Jumping Beans allows them to survive in their desert environment by avoiding direct sunlight.

P1.194 LANIYAN, AA*; STAAB, KL; McDaniel College; *aal005@mcdaniel.edu*

The composition of Meckel's cartilage in the Gambusia affinis jaw: is there histological evidence for intramandibular bending?

Teleost fishes have a lower jaw that contains three fused bones: the dentary, angular, and articular. In adults, these bones surround the Meckel's cartilage (MC). Members of at least ten lineages of teleosts, including derived poeciliids, have an independently derived "extra" joint between the dentary and the angulo-articular, the intramandibular joint (IMJ). The evolutionary morphology of the IMJ is less understood. The IMJ in *Poecilia spp.* is spanned by the MC, which bends during feeding. Meckel's cartilage in *Poecilia* is non-homogenous, where the middle of the cartilage is more cellular with a noticeably less amount of extracellular matrix (ECM) at the location where bending occurs compared to the articulation points with the bones. This non-homogeneity of MC is uncommon among teleosts. Previous studies show that mosquitofish, *Gambusia affinis*, unlike their poeciliid relatives, do not possess an IMJ; however, the dentary and angulo-articular are not solidly fused in *G. affinis*, so it is possible that slight intramandibular bending has been undetected in this species. The purpose of this study was to identify the composition of the MC in adult *G. affinis* to provide clues to the evolution of the IMJ in this lineage. We hypothesized that the MC in *G. affinis* is also non-homogenous, similar to *Poecilia spp.*, but to a lesser degree given a lack of intramandibular bending during feeding. We found that the MC in *G. affinis* is homogenous with a similar proportion of cells to ECM throughout the structure, further corroborating that Meckel's cartilage is not bending in this species. Taken together, these data suggest that in poeciliids, the dissociation of the dentary and anguloarticular may have occurred prior to changes in the cellular morphology of Meckel's cartilage in the IMJ.

P1.135 LANTZ, SM*; BOERSMA, J; SCHWABL, H; KARUBIAN, J; Tulane University, Washington State University; *slantz@tulane.edu*

Early Molting Red-backed fairywren Males Acquire Ornamented Plumage in the Absence of Elevated Androgens

Sexual ornaments, including plumage ornamentation, are often studied during breeding periods even though signal development can take place months earlier. This temporal disconnect potentially obscures the proximate mechanisms that underlie signal expression and enforce honesty. Theory and empirical evidence predict that testosterone may be a proximate signal for sexual signals such as plumage coloration, but substantial costs associated with testosterone might instead lead to selection for alternative, and potentially less costly, mechanisms. We studied the correlation between androgen levels and expression of ornamented plumage in adult red-backed fairywrens (*) several months before the breeding season, when signal production occurs in some males, while other males delay molt until the onset of breeding. We found that, during this period, ornamented males, unornamented males and females all had low plasma androgen levels that did not differ from each other. Variation in androgen levels was not related to phenotype or molt status (presence/absence of molt). These findings contrast with previous research conducted immediately prior to breeding in a different population of this species, which suggested that testosterone induces prenuptial molt and acquisition of ornamented plumage in males. We suggest that disparate results between these studies may be due to age-dependent differences between after-second-year vs. second-year males, but also discuss temporal differences and the possibility of alternate mechanisms for signal production in geographically distinct populations. More broadly, we suggest that signal acquisition in the absence of elevated androgens may have important adaptive benefits, particularly in unpredictable or challenging environments.*

S1.11 LANY, N.L.*; ZARNETSKE, P.L.; GOUHIER, T.C.; Michigan State University, Northeastern University; *lanynina@msu.edu*

Incorporating the effects of climate change on species interactions into species distribution models

Species distribution models typically use correlative approaches that characterize the species-environment relationship using occurrence or abundance data for a single species (i.e., the Grinnellian niche). However, species' distributions are determined by both abiotic conditions and interactions with other species in the community (i.e., the Eltonian niche). Therefore, climate change is expected to impact species through direct effects on their physiology and indirect effects propagated through their resources, predators, competitors and mutualists. Furthermore, the species that comprise a community may not exhibit the same response to abiotic conditions, and as a result, the strength of species interactions could change across a species' range or with climate change. Here, we develop a multi-species dynamic distribution model that estimates the species-environment relationship simultaneously for a subset of strongly interacting species in a community. Our approach also incorporates a competition module commonly used in community ecology that models the dynamic feedbacks that arise from intraspecific density-dependence and interspecific interactions. A main innovation of this study is that our models capture the way the intra- and interspecific interaction coefficients in the community module vary with abiotic conditions. We use a hierarchical, multivariate Bayesian approach and illustrate the model with a spatially-explicit time series of data on the abundance of interacting species in the rocky intertidal zone. This work bridges the disciplines of biogeography and community ecology to develop tools to better predict the higher-order, indirect effects of climate change on ecological communities.

P2.70 LANZA, AL*; SEAVER, EC; University of Florida;
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The organizing role of TGF beta signaling in axis formation of the annelid Capitella teleta

Embryonic organizers are signaling centers that coordinate developmental events within an embryo. Localized to either an individual cell or group of cells, embryonic organizing activity induces the specification of other cells in the embryo and can influence formation of the body axes. In the spiralian *Capitella teleta*, previous cell deletion studies have shown that organizing activity is localized to a single cell, 2d, and this cell induces the formation of the dorsal-ventral and left-right axes. In this study, we attempt to identify the signaling pathway responsible for the organizing activity of 2d. Embryos at stages when organizing activity is occurring were exposed to various small molecule inhibitors, raised to larval stages, and scored for axial anomalies analogous. Our results show that interference with the TGF beta signaling pathway through a short 3 hour exposure to the inhibitor SB431542 results in larvae that lack bilateral symmetry and a detectable dorsal-ventral axis. However, interference with the BMP signaling pathway through exposure to the inhibitor dorsomorphin dihydrochloride does not initially appear to play a role in 2d's specification of the dorsal-ventral or the left-right axe¬is. These results differ from a recent report that in the gastropod *Ilyanassa*, a member of a sister clade to *Capitella*, BMP signaling is crucial for dorsal-ventral axis patterning. These and further investigations will shed light on the identity of the 2d signaling pathway involved with *Capitella* axes formation, and contribute to our understanding of how changes in developmental programs lead to evolution of body plans.

P2.78 LARIVEE, M.L. *; BOUTIN , S. ; MCADAM , A.; HUMPHRIES , M.M. ; Government of Yukon , University of Alberta , University of Guelph , McGill University ;
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Plasticity in resting metabolic rate in response to food availability in free-living North American red squirrels

Animals express physiological and behavioural plasticity to cope with changes in food availability. Resting metabolic rate (RMR) is a highly plastic physiological trait defined as the basic energetic cost of survival. To explore whether individuals are more likely to sustain increases in maintenance costs when food availability is high, we compared food-supplemented and control populations of free-living North American red squirrels *Tamiasciurus hudsonicus* at the beginning of the breeding season. We found that measures of whole-animal RMR for supplemented squirrels were 16 percent higher compared to controls and 12 percent higher once differences in body mass were considered. Supplemented females were characterized by earlier parturition dates than controls. Two months following the removal of supplementary food, no difference in RMR was detected between food supplemented and control groups, though breeding females tended to maintain a higher RMR than non-breeding females and males. We conclude that breeding red squirrels are enabled to increase maintenance costs when food availability is high and that this response is reversible when sufficient food is no longer available.

7.5 LARSON, D; University of Alaska Fairbanks;
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Parasite Survival in a Freeze-Tolerant Host

I examined whether larval cysts of the trematode *Ribeiroia ondatrae* can survive within freeze-tolerant wood frogs (*Lithobates sylvaticus*) and whether survival was dependent on host physiological adaptations to freezing. I exposed 107 wood frog tadpoles from interior Alaska to 30 *R. ondatrae* cercariae each. Metamorphosed frogs were divided into three groups: unfrozen control, single freezing event, or repeated freeze-thaw. For all groups, parasites were considered alive at experiment end if motility was observed either within cysts or after excystment. Control wood frogs (n=22) were held for two weeks at 2°C. Wood frogs experiencing a single freezing event (n=26) were cooled from 2°C to -6°C over 12 hours, nucleated with ice to initiate freezing at -1.5°C, and then held for two weeks at -6°C. Wood frogs experiencing repeated freeze-thaw (n=29) were cooled over 12 hours from 2°C to -6°C, nucleated at -1.5°C, and then warmed over 12 hours to 2°C; this cycle was repeated twice before wood frogs were then held at -6°C for two weeks. Wood frogs (n = 10 per group) averaged 18.7±2.7 motile metacercariae and there were no changes in motile metacercariae abundance among unfrozen wood frogs 2 weeks after exposure. Freezing significantly impacted parasite survival. No parasites survived in the single freezing event group; however, parasite survival was 23% in the freeze-thaw group. Parasite survival had a positive linear relationship with the concentration of cryoprotectant (glucose) produced by the frog host. My results demonstrate that ecologically relevant conditions must be used to accurately evaluate parasite survival in vitro. This research also demonstrates how overwintering physiology of a host can detrimentally affect parasite survival. Additionally, these results indicate overwintering parasites may use host cryoprotectants to survive freezing.

P2.248 LARTER, KF*; REES, BB; UNIVERSITY OF NEW ORLEANS; *brees@uno.edu*

Effects of Hypoxia and Euthanasia on Blood and Gill of the Gulf Killifish, Fundulus grandis

In many experiments, euthanasia, or humane killing, of animals is necessary. Some methods of euthanasia cause death through cessation of respiratory or cardiovascular systems, causing oxygen levels of blood and tissues to drop. For experiments where the goal is to measure the effects of environmental low oxygen (hypoxia), the choice of euthanasia technique, therefore, may confound the results. This study examined the effects of four euthanasia methods commonly used in fish biology (overdose of MS-222, overdose of clove oil, rapid cooling, and blunt trauma to the head) on variables known to be altered during low oxygen exposure (hematocrit, plasma cortisol, blood lactate, and blood glucose) and on variables reflecting gill damage (trypan blue exclusion) and energetic status (ATP, ADP, and ATP:ADP ratio). These variables were measured in Gulf killifish, *Fundulus grandis*, after exposure to normal or reduced oxygen levels (24 h at 0.86 mg O2 l^{-1}; = 17 mm Hg = 2.2 kPa). During these analyses, it was necessary to modify the technique for ATP and ADP measurement due to high calcium content of the biological samples (intact gill arches). Regardless of method of euthanasia, hypoxia led to higher hematocrit, blood lactate, and plasma cortisol. Independent of oxygen level, MS-222 led to higher hematocrit and lower gill ATP:ADP ratios compared to other methods of euthanasia. Thus, the choice of euthanasia method should be appropriate for the experimental design, species studied, and variables measured. For hypoxia research, in particular, caution should be exercised when using methods that act through respiratory or cardiovascular arrest.

11.1 LASALA, JA*; HUGHES, CR; WYNEKEN, J; Florida Atlantic University, Boca Raton, FL; *jlasala321@gmail.com*
Promiscuity in marine turtles: evolutionary push for population stability?
The recovery of threatened or endangered organisms is complicated by the need for simple and effective methods of quantifying individuals. If the organism is difficult to access, its behavior is elusive, or some individuals are widely observable and others are cryptic, a census count is inadvisable. Sex ratios, population size, and relatedness of individuals are important metrics of population status, but if the organism is mysterious, these questions can go unanswered. For marine turtles, hatchling sex ratios are determined through patterns/proxies of temperature sex determination (TSD) and in Florida these mostly result in a female bias. Adult sex ratios typically differ from those estimated for offspring and so adult sex ratios are primarily estimated through counts of nesting females. This method, unfortunately, leaves the number of adult males to be enigmatic. Alternative assessment techniques include using molecular markers to identify parentage of individuals as well as fundamental relationships among males and females within a population. By using exclusion analysis (comparing maternal genotypes to offspring genotypes), male numbers can be estimated with greater accuracy, and those results can be applied to estimate effective population size. We compare the numbers of males and females contributing to a loggerhead sea turtle (*Caretta caretta*) nesting assemblage in southern Florida and determined that these turtles are promiscuous. However, we did not find repeating males, suggesting that the number of successful males may be higher than previously expected. In a species that has TSD and highly female biased hatchling sex ratios, this high occurrence of multiple paternity in a small nesting assemblage could signal an evolutionary shift to stabilize population sex ratios even as temperatures continue to rise.

120.6 LASCALA-GRUENEWALD, DE*; MEHTA, R; LIU, Y; DENNY, MW; Stanford University, Uppsala University; *dianalg11@gmail.com*
Fat-tailed Foraging Strategies Require Energetic Trade-offs in Patchy Environments
Fat-tailed foraging strategies have been hailed as optimal for patchy environments. Diverse organisms have been documented performing Lévy walks, which are fat-tailed foraging strategies with step lengths drawn from power-law distributions with exponents near -2. But like other fat-tailed strategies, Lévy walks entail relatively high probabilities of very long steps, and therefore involve trade-offs between energy gained through food consumption and energy lost during travel. Under what environmental conditions are these strategies energetically favorable? To explore this question, we constructed an agent-based model that simulated a single forager searching for food in a 2-dimensional world. During each time step, the forager looked for food within its range of perception. If it could perceive food, it moved to the food and consumed it. Otherwise, it drew a step length from a power-law distribution. We ran simulations on 21 worlds, which contained 0.5-15% food cover arranged in randomly distributed, non-overlapping patches, and varied the forager's power-law exponent (α), range of perception, and whether that range of perception was anteriorly biased. For each simulation, we measured the number of times the forager consumed food, and calculated the cost-benefit ratio. We found that the four-way interaction between % food cover, power-law exponent, range of perception and anterior bias was significant for all three response variables. But in general, a fat-tailed foraging strategy (α=-1) resulted in significantly more food consumed than a thin-tailed strategy (α=-3). However, the beneficial effect of the power-law exponent was almost completely eliminated when considering cost-benefit ratios.

143.3 LASHLEY, MA*; BARTON, BT; JORDAN, HR; TOMBERLIN, JK; Mississippi State University, Texas A&M University; *marcus.lashley@msstate.edu*
Community responses to an experimental mass mortality event and the role of vertebrate scavengers
Mass mortality events (MMEs), in which large numbers of animals die in a relatively short period of time, are increasing in frequency and are linked to climate change. How MMEs impact ecosystems and how quickly—or if—ecosystems recover from these disturbances are unanswered questions. MMEs are unpredictable, occurring throughout the world without warning. Consequently, studies have been reactive, and initiated too late for baseline data to address questions about ecosystem resistance and resilience. In contrast, we gathered baseline data and then simulated MMEs in a controlled experimental design. To acquire sufficient biomass, we used feral swine (*Sus scrofa*) carcasses that resulted from state-wide trapping efforts. At each of five sites, we established four 18m2 circular plots, which were randomly assigned to one of four treatments in a factorial design that crossed carcass addition and vertebrate scavenger exclosures (wire fencing and netting roof). Sites were randomly assigned to one of five biomass treatments (25, 60, 180, 360, 725 kg per plot), with more than 2700 kg of carcasses used in the whole experiment. The experiment is ongoing, but initial results have shown effects on plant, invertebrate, and vertebrate communities, as well as soil properties. We found a significant and interactive effect of biomass treatment and exclosures, indicating the importance of vertebrate scavengers increased with carrion biomass. Excluding vertebrate scavengers reduced decomposition rate and significantly increased carrion fly production, probably by reducing competition for carrion and consumption of fly larvae. Although preliminary, our results are consistent with the hypothesis that vertebrate scavenger communities can mitigate or mask some of the effects associated with MMEs.

69.1 LASLO, M*; HANKEN, J; Harvard University; *mlaslo@fas.harvard.edu*
Expression of thyroid hormone receptors and deiodinases in the direct-developing frog Eleutherodactylus coqui
Direct development is a reproductive mode in anurans that has evolved independently at least a dozen times. Direct-developing frogs, including the common coquí, *Eleutherodactylus coqui*, hatch from terrestrial eggs as miniature adults. While their embryonic development resembles metamorphosis in several respects, characters develop in a different sequence compared to metamorphosing frogs. In metamorphosing frogs, for example, limb growth and tail resorption both occur following thyroid gland formation. In contrast, limbs in direct-developing frogs develop before the thyroid. This suggests that limb development is either thyroid hormone (TH) independent or mediated by maternally derived TH provisioned in the egg before fertilization. Changes in thyroid hormone provisioning, metabolism, or action may thus underlie the evolution of direct development. Specifically, maternally derived TH and changes in temporal or spatial expression of the nuclear thyroid receptor (TR) α, TRβ, deiodinase type II, or deiodinase type III in the target tissue could facilitate tail resorption and early development of limbs. Expression of TR in *E. coqui*, suggests that tail resorption is mediated by TH. Similarly, TR expression dynamics in the limb approximate those in the developing limb of the metamorphosing frog *Xenopus laevis*, which is dependent on TH. Liquid-chromatography mass-spectrometry indicates that maternally derived TH is present in *E. coqui* at the onset of limb development. These data suggest that the *E. coqui* limb is at least TH competent and that thyroid-mediated embryonic development may begin much earlier than previously thought. Maternally provisioned TH may confer developmental flexibility that facilitates the evolution of direct development.

76.4 LATIMER, CE*; COOPER, SJ; KARASOV, WH; ZUCKERBERG, B; University of Wisconsin-Madison, University of Wisconsin-Oshkosh; *celatimer@wisc.edu*

Metabolic Constraints Differentially Affect Foraging and Survival of Birds in Human-Modified Landscapes

For birds overwintering in temperate regions, foraging is arguably one of the most important behaviors affecting fitness. While many factors influence foraging, few studies have addressed the relationship between behavior, energy constraints and its consequences on survival. We examined how the metabolic flexibility of individual Black-capped Chickadees (*Poecile atricapillus*) influenced their foraging response to temperature changes across a gradient of forest fragmentation. We predicted individuals with low metabolic flexibility would be more energetically constrained, forcing them to forage more under harsh winter conditions, and increasing costs of mortality due to the tradeoff between foraging intensity and predation risk. Lastly, we expected birds in fragmented landscapes would have higher metabolic flexibility due to greater selective pressures on birds with low metabolic flexibility. During winter 2014/15, we quantified foraging behaviors of birds at supplemental feeding stations using radiofrequency identification. We calculated metabolic scopes (summit - basal metabolic rate) for 28 birds as a snapshot of metabolic flexibility. Low scope birds were more energetically constrained and significantly increased their feeder visitation as temperatures declined over winter. These birds were 70% less likely to survive the winter compared to individuals with high metabolic scope. Lastly, birds in fragmented landscapes had 16% higher scope, suggesting greater selective pressures against more energetically constrained behavioral phenotypes. To our knowledge, this is the first study to examine the link between energy constraints and foraging on survival of birds in human-modified landscapes.

P3.119 LATIMER, CE*; MILLER, C; ZUCKERBERG, B; University of Wisconsin-Madison; *celatimer@wisc.edu*

Surviving the Heat: Climatic Drivers of Northern Cardinal Bill Morphology in Space and Time

Allen's Rule is a biogeographic rule that predicts appendage sizes of organisms vary with latitude in order to minimize or maximize exposed surface area and facilitate heat retention or dissipation in cold and hot climates, respectively. Due to its vascularization, the avian bill plays an important thermoregulatory role, and is therefore likely to conform to these predictions. While Allen's rule has been examined in relation to bird bill sizes over broad geographic gradients, there remains little support for morphological variation over time. Over the past several decades, many regions of North America have demonstrated a consistent increase in temperature due to modern climate change. However, climate change is occurring non-uniformly through space and time, and thus, we expect its impact on populations should vary geographically. We hypothesized that Northern Cardinal (*Cardinalis cardinalis*) bill size and bill size variation would decrease with increases in latitude. Additionally, we hypothesized that as minimum average temperatures increase over time, Northern Cardinal bill size would also increase over time. We obtained measurements of bill surface area for Northern Cardinal museum specimens collected over an 85-year period (n =559) and tested the effects of climate variation. We found that bill sizes decreased with increases in latitude, and that the variation in bill size was greater in southerly regions than in northerly regions. We also found that bill sizes increased over time due to increasing minimum average temperatures, and that this relationship has strengthened over time. These results imply that bill size varies as a function of temperature over space and time, following the predictions of Allen's Rule.

P2.104 LATTIN, CR*; GALLEZOT, J; CARSON, RE; Yale University; *christine.lattin@yale.edu*

Availability of dopamine D2 receptors in striatum predicts behavioral response to captivity in a wild songbird

Captivity is a potent chronic stressor for many wild animals, although different animal species, and different individuals within a species, display wide variation in their tolerance to captivity stress. We previously observed that wild-caught house sparrows (*Passer domesticus*) increased the frequency of two repetitive behaviors, beak wiping and feather ruffling, with time in captivity. Because repetitive, stereotyped behavior can also be induced through drug-induced stimulation of the dopamine system, we hypothesized that individual variation in D2 dopamine receptors would predict the frequency of stereotyped behaviors in response to captivity stress. We examined D2 receptor availability in striatum using an in vivo imaging technique, positron emission tomography (PET) with the D2 antagonist ^{11}C-raclopride. We found that D2 receptor availability (binding potential) in striatum 24 h after capture predicted the frequency of several behaviors after 1 month in captivity, with individuals with higher D2 binding potential displaying significantly lower overall activity levels and beak wiping (although not feather ruffling) behavior than those with lower D2 binding potential. Furthermore, in the subset of individuals that were imaged a second time, D2 binding potential decreased with time in captivity. Thus, high concentrations of D2 receptors in striatum may make some individuals resilient to the behavioral effects of captivity stress. To the best of our knowledge, this is the first use of PET imaging to quantify brain receptors in any wild animal species, and demonstrates the usefulness of this technique in elucidating how individual variation in neuroendocrine phenotypes can predict behavior.

65.6 LAU, C. L. *; JACOBS, D. K.; Univ. of California, Los Angeles; *clivelflau@gmail.com*

Water extraction and loss of species distinction in a Colorado Delta endemic silverside fish— Colpichthys hubbsi

Diversion of water from the Colorado River has converted the unique Colorado Delta from variably fresh and brackish environments to marine and hypersaline conditions - paralleling changes due to water extractions around the world. Diversions became extreme subsequent to the construction of Hoover Dam in 1935 and has now dramatically altered the delta environment, potentially impacting the Delta endemic fauna within the biodiverse northern Gulf of California. Here we explore the potential impact of loss of freshwater in the system on a poorly studied Delta endemic silverside, *C. hubbsi* (Crabtree), relative to its more widely distributed sister species, *C. regis* (Jenkins and Evermann), in the Gulf endemic genus *Colpichthys*. Using morphologic, mitochondrial, microsatellite and nuclear sequence data we document hybridization between historically differentiated species. This suggests that the loss of freshwater may have dissolved the ecological factors that once separated these species. However, we do not find strong evidence of a population bottleneck in *C. hubbsi*. Thus, while there may not be a dramatic impact of population reduction at this time, the species appears to be at risk due to introgression of genes from its sister following loss of ecologic separation. Further work on this system to identify the changing selection regime in genes under selection and to establish the pattern of genetic introgression using high throughput sequencing approaches is merited.

52.7 LAUDER, GV*; THORNYCROFT, PJM; KHAN, M; WAINWRIGHT, DK; ANDERSON, EJ; WEN, L; ALVARENGA, J; AIZENBERG, J; Harvard Univ., Grove City College, Beihang Univ.; *glauder@gmail.com*

Bioinspired Lubricant-Infused Surfaces Enhance Aquatic Locomotion

Slippery surfaces are common in biology, and have important roles to play as an interface between organismal tissues and the environment. In particular, mucus coatings on fish have been proposed to reduce drag during swimming. But little is known about the properties of fish mucus, and previous work on fish mucus has focused on static testing and not on analyzing the effects on dynamic, swimming performance. We measured viscous properties of trout mucus using a cone-plate viscometer, and used aluminum plates coated with Krytox viscous lubricant to test the effect of lubricants on swimming thrust and efficiency relative to a smooth and unlubricated control. Trout mucus is non-Newtonian and has a complex composition. We prepared the surface of aluminum panels by functionalizing and texturing them in several ways to hold Krytox lubricant which has a similar viscosity to trout mucus. This process greatly reduced the loss of lubricant during testing. Testing of coated panels relative to controls revealed that the slippery coating enhanced the lift to drag ratio by 2 - 10%. Dynamic testing of swimming panels moved in heave and pitch showed that coated panels improved swimming efficiency by 3 - 5 % over a wide range of motion parameters, and increased thrust of 4% was also observed over nearly the entire range of tested motions. Measurements of boundary layer flows on coated versus uncoated flat plates confirmed that the Krytox slippery coating reduced skin friction drag by ~5% under laminar flow conditions. These results show that slippery coatings can improve swimming performance over a wide range of both static and dynamic conditions, and do not simply enhance propulsion over a limited range of motion parameters.

P1.175 LAURENCE-CHASEN, JD*; RAMSAY, JB; BRAINERD, EL; Brown University, Westfield State University; *jeffrey_laurence-chasen@brown.edu*

XROMM Analysis of Prey Processing in a Stingray, Potamotrygon motoro (Elasmobranchii: Batoidea)

Unlike other elasmobranchs, batoids exhibit a euhyostylic jaw suspension, characterized by a loss of an anterior connection between the upper jaw and cranium. This leaves the paired hyomandibulae as the sole suspensory elements. The reduced jaw suspension increases mobility of the individual jaw elements, allowing batoids to move their jaws more freely while capturing and processing prey. However, the extent of jaw mobility is difficult to visualize and quantify in 3-dimensions with traditional high-speed videography. We used marker based XROMM (X-Ray Reconstruction of Moving Morphology) to measure the motion of the cranium and the left and right palatoquadrate (PQ) and Meckel's cartilage (MC) during prey processing in a freshwater stingray, *Potamotrygon motoro*. The resultant animations from feeding trials recorded at 200 Hz confirm previous observations that the jaws are highly mobile during processing. In 14 consecutive chewing cycles from one individual, we found that the jaw joint, and by proxy the mandibular arch, depressed ventrally up to 5.0 mm relative to the cranium. The PQ and MC rotated up to 40 and 30 degrees about their long axes, respectively. The left and right MC rotated up to 25 degrees about their symphysis, with substantial rotations about two axes: one oriented dorsoventrally and the other rostrocaudally. The distances between markers within each cartilage stayed consistent (+ 0.049 mm), indicating high precision in the XROMM animations, and suggesting high stiffness in the cartilages themselves. This first application of XROMM to study batoid feeding provides new quantitative insight into a highly kinetic system, and further validates the method's effectiveness for the study of cartilaginous fish feeding.

P1.228 LAURENT, CM*; SCHNEIDER, P; DYKE, GJ; BOARDMAN, RP; PALMER, C; COOK, RB; DE KAT , R; University of Southampton, University of Debrecen; *cl20g10@soton.ac.uk*

Laminar Layup Varies Around And Along Bird Feather Shafts.

Feathers have been evolving for more than 130 million years under selection pressures to become light, stiff and strong. However, a detailed investigation into their material structure (and properties) is still lacking. Previously, using nanoindentation and µCT, we have shown that feather shafts are fibrous laminar composites and that their structure varies between species. Here we show a feather's structure also varies around its circumference and along its length. We present the first synchrotron radiation computed tomography (SR-CT) dataset, from which we infer fibre orientation inside the feather shaft cortex. Scans of different locations on the shaft show that the number of laminae and fibre alignment within feather shafts of the heaviest flying bird, the Swan, are not fixed; they vary both around the circumference of the shaft and along its length. Our work opens a new perspective on a research question in avian biology which has remained unanswered for more than 30 years: what is the modulus of feather-keratin? To answer this question, one needs to take into account not only the shaft's geometry but also its layup.

P3.42 LAURENZANO, C*; SCHUBART, CD; University of Louisiana at Lafayette, Universität Regensburg; *claudia.laurenzano@louisiana.edu*

Contrasting patterns of genetic structuring in two western Atlantic fiddler crabs

Fiddler crabs (Brachyura, Ocypodidae), like many other marine organisms, disperse via planktonic larvae. A lengthy pelagic larval duration is generally assumed to result in genetic connectivity even among distant populations. However, major river outflows, such as of the Amazon or Orinoco, or strong currents may act as phylogeographic barriers to ongoing gene flow. For example, the Mona Passage, located between Puerto Rico and Hispaniola, has been postulated to impair larval exchange of several species. In this study, Cox1 mtDNA data was used to analyze population genetic structure of two fiddler crab species from the western Atlantic, comparing the continental coastline and Caribbean islands. The results indicate genetic homogeneity in *Minuca rapax* among Atlantic (continental) populations (Suriname, Brazil), whereas Caribbean populations show significantly restricted gene flow among the constituent islands and towards continental populations. Our data support the hypothesis of the Mona Passage hindering larval exchange. Contrastingly, Caribbean *Leptuca leptodactyla* populations appear to be devoid of detectable variation, while Atlantic-continental (i.e. Brazilian) populations show much higher haplotype and nucleotide diversities and display slight genetic differentiation among populations within the Atlantic region, though not statistically significant. Both species show a pronounced divergence between regions, supporting the presence of a phylogeographic barrier.

P3.49 LAUTERBUR, ME*; TONGASOA, L; PERALTA, J; JACOX, A; CONCHEIRO-GUISAN, M; WRIGHT, PC; Stony Book University, University of Antananarivo, John Jay College of Criminal Justice, John Jay College of Criminal Justice, Stony Brook University; *mary.lauterbur@stonybrook.edu*

Peeing Poison: The Biochemistry of Bamboo Lemur Cyanide Survival

Bamboo lemurs (*Prolemur simus* and *Hapalemur ssp.*) survive eating typically deadly concentrations of cyanide in their natural diet of bamboo. This trait is an evolutionary novelty, making bamboo lemurs the only mammals known to survive such high cyanide concentrations. How they do so has remained a mystery for nearly 30 years. To understand the nature of this adaptation we must understand the biochemical and metabolic processes at work, but the Critically Endangered status of these species limits options for study. We used a novel approach: cyanide is excreted in unknown form in the urine of these species. The form of cyanide excreted (cyanide ion or a detoxification product) is informative of the biochemical or metabolic process allowing these species to survive. To determine the chemical structure of excreted cyanide, we collected urine samples from wild (N = 46) and captive (N = 7) bamboo lemurs (*P. simus*, *H. aureus*, and *H. griseus*) from Madagascar and comparative samples from closely related non-bamboo eating (thus non-cyanide consuming) lemurs at the Duke Lemur Center. We then adapted gas chromatography-mass spectrometry (GCMS) analytical methods to test for cyanide (CN^-), thiocyanate (SCN^-, the primary mammalian cyanide detoxification product), and the cyanide metabolite ATCA (2-aminothiazoline-4-carboxylic acid) in lemur urine. Comparing cyanide consuming and non-consuming species allows inference of the biochemical and metabolic processes acting on consumed cyanide. The preliminary results of these chemical analyses provide the first evidence for the biochemical mechanisms behind this extreme dietary adaptation.

129.5 LAW, CJ*; YOUNG, C; MEHTA, RS; Univ. of California, Santa Cruz, California Department of Fish and Wildlife; *cjlaw@ucsc.edu*

Ontogenetic Scaling of Theoretical Bite Force in Southern Sea Otters (Enhydra lutris nereis)

Sexual dimorphism attributed to niche divergence is often linked to differentiation between the sexes in both dietary resources and traits related to feeding and resource use. Recent studies have indicated that southern sea otters (*Enhydra lutris nereis*) exhibit intersexual differences in the degree of dietary specialization as well as in craniomandibular size and shape. Whether these differences translate to differences in functional traits between the sexes remains to be investigated. To test the hypothesis that scaling patterns of bite force, a metric of feeding performance, exhibit intersexual differences, we calculated theoretical bite forces of 55 naturally deceased southern sea otters spanning the size ranges encountered over ontogeny. We then used standardized major axis regressions to simultaneously examine the scaling patterns of theoretical bite forces and morphological components across ontogeny and assess whether these scaling patterns differed between the sexes. We found that positive allometric increases in theoretical bite force resulted from positive allometric increases in physiological cross-sectional area for the major jaw adductor muscle and in mechanical advantage. In our analysis of sexual dimorphism, we found that scaling patterns of theoretical bite force and morphological traits do not differ between the sexes over ontogeny. However, adult male sea otters exhibited greater absolute bite forces as a result of their larger sizes rather than differences in scaling patterns in any particular trait. Our results provide some support for the niche divergence hypothesis throughout late adulthood. Future work may link intersexual differences in feeding functional morphology with foraging ecology to further validate the role of niche divergence in the maintenance of sexual dimorphism in sea otters.

P2.223 LAYTON, TE*; HOPKINS, SR; WOJDAK, JM; MCELMURRAY, P; Radford University, Virginia Tech; *tlayton2@radford.edu*

A mark-recapture study of trematode parasitim in Helisoma trivolvis

Parasites with complex life cycles face a paradox - they need to infect intermediate hosts with enough frequency and intensity to ensure transmission to their hosts, but not at such high intensity that their intermediate hosts die before transmission can occur. Echinostome parasites encyst in snails as second-intermediate hosts. These cysts are dormant stages that do not feed, and thus do not use up host resources and thus were thought to be relatively benign. However, in recent field surveys, we found that average cyst infection intensities declined through the season, although new cyst-free snails were not entering the population. We hypothesized that heavily-infected snails were dying sooner than snails with lower infection intensities, either because (1) encystation injured heavily infected snails enough to kill them or (2) heavily infected snails were more likely to be predated. To evaluate these hypotheses, we performed a mark-recapture experiment using lab-raised snails that were either uninfected or experimentally infected.Recapture efforts continue, but thus far 12% of snails have been recovered. Snail recapture rates did not differ between uninfected and infected snails, but infected snails were significantly more likely to have died before recapture. Snails exposed to parasites were also more likely to die in the laboratory before release than unexposed snails. Shells of dead snails collected in the field did not have any signs of shell damage, suggesting that snails died of infection or predation by predators that access the animal via the shell aperture. Parasite-induced mortality from enchinostome cysts may play an important role in snail population dynamics, and by killing intermediate hosts, high infection intensities may limit transmission of the parasites to the definitive hosts.

P3.149 LE POGAM, A*; LOVE, O.P; VEZINA, F; Université du Québec à Rimouski (Québec), Canada, BOREAS, CEN, CSBQ, University of Windsor (Ontario), Canada, Chair in Integrative Ecology ; *audrey.lepogam@uqar.ca*

Influence of body remodeling on metabolic performance of snow buntings preparing for a long distance migration towards Arctic breeding grounds

Long distance migration is known to involve significant physiological changes. In the spring, birds develop their flight muscles and build considerable fat reserves to get the fuel and exercise capacity required for their journey. However, since flight muscles also play an important role in avian shivering thermogenesis, larger muscles during migration could also be advantageous for birds like the snow bunting (*Plectrophenax nivalis*), a passerine that faces cold conditions on arrival on its Arctic breeding ground. We investigated this potential phenomenon working with outdoor captive snow buntings during three consecutive spring fattening events. Our results show that buntings increased their body mass by more than 40% between early March and late April. This was associated with an increase of fat reserves by more than 370% and with an increase in thickness of their pectoral muscles. As expected, the birds also improved their exercise capacity and basal metabolic rate. However, as buntings begin fattening at the end of winter, cold endurance was already high and remained comparable to wintering levels throughout fattening, despite much warmer spring temperatures. Thermogenic capacity varied independently from changes in pectoral muscle size and lean mass. Our results therefore suggest that snow buntings may benefit from their migratory phenotype to face cold arrival conditions but that improving their thermogenic capacity does not require changes in muscle size.

46.5 LEACH, W.B.*; PERES, R.; REITZEL, A.M.; University of North Carolina, Charlotte, University of Hawaii Cancer Center; *wroger11@uncc.edu*

Diel Lighting Impacts on Behavior and Opsin Expression in a Coastal Cnidarian

Species occurring in aquatic habitats are subjected to a range of optical stimuli. Previous investigations have shown that Nematostella vectensis, a coastal cnidarian, responds to diel lighting patterns with an endogenous circadian clock, however, the impact of variable light remains unknown. In order to investigate how variation in optical stimuli impacts this anemone, we characterized differentially expressed genes and associated behaviors in N. vectensis as individuals responded to variable lighting conditions (duration and wavelength). Using microarrays we measured transcriptome-wide oscillations in gene expression to determine which genes cycle in light:dark (LD) conditions and which of these continue cycling after removal of the light cue (dark:dark, DD). Comparisons of LD and DD exposed animals revealed approximately 220 genes with significant differences in expression in light:dark culturing, with more than 85% of these losing differential expression within 4-days after removal of light cue. Using quantitative PCR we further investigated subsets of these genes in order to elucidate the impact of light cycling on optically related molecular pathways, some of which are regulated by a circadian clock - i.e. cell cycle/cell death, metabolism, and expression of light-sensitive proteins (opsins). We also used anemone locomotion analyses to determine if isolated portions of the visible spectrum elicited an alternative behavioral response, with preliminary results indicating they respond to all light wavelengths. Overall, these analyses provide insight into how this invertebrate responds to diel lighting conditions and wavelength, while shedding light onto the mechanism of cnidarian circadian clocks.

144.6 LEARY, CJ*; CROCKER-BUTA, SP; Univ. of Mississippi; *cjleary@olemiss.edu*

Acute Stress is a Target of Intra- and Intersexual Selection in the Green Treefrog, Hyla cinerea: Implications for Fitness, Honest Signals, and the Evolution of Endocrine-based Acoustic Armaments

The acute endocrine stress response plays an integral role in mediating trade-offs between current and future reproduction, suggesting that variation in acute stress responsiveness can be a critical determinant of fitness. How these principles unfold in the context of sexual selection is, however, poorly understood. Here, we build upon the "acute stress-fitness" framework in the context of intra- and intersexual selection in the green treefrog, *Hyla cinerea*. Males of this species produce vocalizations that stimulate production of the stress hormone corticosterone (CORT) in rival males, suggesting a central role for CORT in male-male competition. We predicted that acoustic stimulation of CORT production functions in an armament capacity by compromising rival male investment in courtship behavior and, hence, attractiveness. Consistent with this prediction, we show that CORT administration to calling males, simulating CORT production during vocal contests, rapidly decreases call duration and increases the probability of aggressive signaling and vocal abandonment - all of which reduce attractiveness to females. CORT-mediated effects were most prominent during simulated male interactions and occurred independently of changes in androgens, indicating that CORT effects are context-dependent and modulate androgen-dependent behaviors. Our results suggest that variation in acute stress responsiveness plays a pivotal role in intra- and intersexual selection and mediating the honesty of sexual signals.

21.1 LEE, DN*; OPHIR, AG; Southern Illinois University Edwardsville, Cornell University; *dnlee5@ymail.com*

Novelty Responses and Individuality of African giant pouched rats

Alternative tactics can arise in which behavior of some individuals systematically differ from others. By investigating the degree of variation that exists in natural populations, we gain insight into how evolution has shaped the 'personality' of individuals and established evolutionary stable alternatives, usually along a continuum. In the first known study to investigate the behavioral scope of *Cricetomys ansorgei*, we examined the spontaneous responses of two study populations of wild-caught African giant pouched rats. One population was examined soon after capture in Tanzania (and released back into the wild at the end of the study) and the other population was transferred to the United States to establish a colony and was examined several months after living in captivity. Presenting a series of novel stimuli tests (light-dark box and novel food items), we measured the proactive-reactive responses of subjects in each study group. In both wild and captive study populations, about a quarter to a third of subjects demonstrated flexible responses to novelty, however these responses were not necessarily correlated across tests. Proactive-reactive responses to novelty may be relevant to understanding the mechanisms responsible for individual variation in exploration and adjusting to captivity.

63.1 LEE, J.S.*; FEARING, R.S.; CHO, K.J.; FULL, R.J.; Univ. of California, Berkeley, Seoul National University, South Korea; *jessica-lee@berkeley.edu*

Crickets Jumping from Diverse Substrates Inspire Leg Design in a Millirobot

Insect legs possess various structures that can enhance interaction with the substrate. We tested how effectively spines at the base of the tibia and foot pads on tarsi provide traction on various surfaces by measuring jump kinetic energy using high-speed video. We stimulated eight crickets, *Gryllus firmus*, to jump from glass, sand, sand paper, and Styrofoam to simulate smooth, granular, rough, and penetrable substrates. We compared control animals to those with disabled foot pads or disabled foot pads and spines. Both substrate and foot structure significantly affected jump kinetic energy. On glass, crickets performed typical leg extension, but friction pads only slipped. Sand reduced jump kinetic energy by 53% compared to sand paper due to yielding effects. Sand paper and Styrofoam resulted in similar performance. Disabling friction pads had no significant effect on jumping from these substrates. Spines increased jumping performance by 82% on Styrofoam, because they permitted penetration. Removing spines did not alter the kinetic energy on sandpaper or sand. Inspired by crickets, we tested the effect of spines and foot pads on a 2.5g insect-inspired jumping robot. Both substrate and foot structure significantly affected jump kinetic energy. Take off angle ranged between 30-40° and was unaffected by surface or foot structure. On smooth surfaces and sand, the robot only slipped. Jump kinetic energy on sandpaper was 43% greater than on Styrofoam, but adding spines increased penetration and jump kinetic energy by 65%, doubling jump distance to 40cm. Adding rubber foot pads allowed the robot to jump on smooth surfaces. Leg spines appear critical for maximum jumping performance on surfaces that allow penetration and foot pads can increase performance on smooth surfaces. Jumping robots can also serve as physical models to generate new hypotheses for jumping animals.

32.4 LEE, D/V*; ISAACS, M/R; BIRN-JEFFERY, A; VOLOSHINA, A/S; ZHAO, G; SEYFARTH, A; DALEY, M/A; University of Nevada Las Vegas, University of Cambridge, Technische Universität Darmstadt, Royal Veterinary College; *david.lee@unlv.edu*

Bipedal Walking of Birds, Humans, and Robots

Bipedal walking is central to our lives yet it cannot be fully understood by studying a single species. Taking a broadly comparative approach, we analyze the walking of 1) humans, 2) birds, 3) simulations of simple models - the inverted pendulum (IP) and bipedal spring-loaded inverted pendulum (BSLIP), and 4) current bipedal robots that embody the IP and BSLIP. For birds and humans, we determined the center of mass dynamics for a full stride of walking using a series of force platforms. Walking simulations were done in Matlab using published code for the IP and BSLIP and metrics for walking robots were taken from the literature. We recorded the walking and running speeds used by birds, along with a range of speeds from the slowest walking through slow running for humans (dimensionless speeds from 0.3 to 1.3). Humans walked at dimensionless speeds between 0.31 and 0.78, whereas birds transition to running before reaching humans' preferred walking speed of about 0.5. Walking speed is limited in both the BSLIP and IP models because they become ballistic at dimensionless speeds of 0.44 and 0.78, respectively. Birds and humans show consistently flat trajectories across the full range of human walking speeds. In contrast IP and BSLIP models have much greater vertical oscillations, with velocity angles becoming two- to three-fold greater than those of birds or humans as walking speed increases. Hence, current walking models produce markedly different center of mass dynamics than those of living bipeds at all but the slowest speeds. In fact, bipedal robots such as Cornell Ranger (IP-based) and ATRIAS (BSLIP-based) walk at such low dimensionless speeds of 0.19 and 0.32, respectively.

P3.74 LEE, CA*; ROMANOVA, EV; BOYKINS, J; KATZ, PS; GILLETTE, R; SWEEDLER, JV; University of Illinois, Urbana Champaign, Georgia State University, Georgia State University; *clee170@illinois.edu*

Peptide profiling of decision network interneurons in the predatory sea-slug Pleurobranchaea californica

How did the simple nervous systems of basal invertebrates elaborate into complex brains? It is reasonable to assume that simple decision making circuits developed into complex ganglia, but this hypothesis remains untested. We explore this question by comparing the transcriptome and peptide profiles of analogous central nervous system (CNS) regions of different invertebrates. If analogous CNS regions are in fact homologous, then they may have similar profiles among related species. These profiles likely become less similar with greater evolutionary distance between species, but structurally conserved peptides should still be traceable in comparative analyses. As a starting point we are characterizing the peptide profiles of critical neurons in the nudipleuran Pleurobranchaea californica. Using mass spectrometry, we have characterized profiles for three neurons: the A1 cell (element of the Turn/Locomotor/Swim network), the buccal ganglion ventral White Cell (feeding command cell), and the buccal ganglion "Efference Copy" cell (provides efference copy of feeding motor activity to the stomach). We find that A1 contains FMRFamide and multiple peptides homologous to Aplysia pedal peptides 3 and 4, the buccal Efference Copy cell contains only LFRFamide and related peptides, and the Ventral White Cell contains multiple peptides including the myomodulins. These results establish a reference point for comparison with other species, in particular other gastropods. Analogous cells have been found in other gastropods, notably Tritonia and Aplysia, enabling us to both look for homologies in peptides and determine if evolutionary distance predicts differences in peptide profiles.

P3.221 LEE, CY*; HUNT, N; FULL, RJ; University of California, Berkeley; *clee16@berkeley.edu*

Rod Running Performance and Inter-Leg Coordination is Unchanged by Inversion

Legged animals are often challenged to change gaits to negotiate destabilizing substrates. In our previous study of branch running (Hunt et. al. 2014), we found that the American cockroach (*Periplaneta americana*) transitioned from an upright to an inverted running gait on smaller diameter rods. The probability of transitioning to an inverted gait increased gradually as an inverse sigmoidal function of rod diameter. To investigate differences in leg coordination between upright and inverted running, we elicited fast escape responses (47.16±11.67cm/s) on an intermediate diameter rod (19.1 mm) where both gaits are employed. We quantified the timing of touchdown and liftoff gait events for all six legs using close-up high speed video. We found that running velocity and duty factor remained comparable across gaits. In addition to similar running performance, we also found no significant difference in the distribution of relative foot touchdown times within the stride. Kinematic data suggests inter-leg coordination changes may be unnecessary to maintain performance on destabilizing substrates, and that an alternating tripod gait is sufficient for both upright and inverted rod running. Examination of tarsal structure contacts during running showed cockroaches used their euplantulae equally often, but used their claws less on inverted compared to upright running. Given the simple control, we are presently exploring the design of a feed forward robot that could traverse branches, pipes and wires.

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Molecular Evolution of Chemoreceptors in Paper Wasps

Chemical communication is used to coordinate the behavior of individuals in insect societies. While the semiochemicals and chemoreceptors of honeybees and multiple ant species have been studied using molecular methods, few studies have examined the genetic basis of chemoreception in the primitively eusocial wasp genus *Polistes*. Paper wasps are a fitting model system for studies of comparative sociogenomics because many species share similar ecologies while exhibiting divergent social systems. We perform *de novo* genome sequencing and chemoreceptor gene annotation in multiple *Polistes* species and in *Mischocyttarus mexicanus*. Next, we examine rates and patterns of evolution of genes encoding odorant receptors (Ors), gustatory receptors (Grs), and ionotropic glutamate receptors (Irs). We compare our findings in *Polistes* to trends in other social insects.

141.3 LEIGH, SC*; HOFFMANN, SL; SUMMERS, AP; GERMAN, DP; University of California, Irvine, Florida Atlantic University, University of Washington ; *scwright@uci.edu*

Spiraling into control: investigating the function of the spiral intestine in Elasmobranchs

Elasmobranchs, the sharks, skates and rays, have an expansion of the intestine that contains a convoluted internal structure called the ‘spiral valve', and thus, this intestinal region is called the spiral intestine (SI). It has been supposed, with little basis, that the SI in sharks slows digesta transit rate. We experimentally tested the flow rate using water. The flow rate is slowed by 3.5x through the SI as compared to the proximal intestines (PI) in *Squalus suckleyi*, *Sphyrna tiburo*, *Sphyrna lewini*, and *Carcharhinus limbatus*; four species with radically different intestinal morphology. We found resistance is higher in the SI compared to the PI. In the SI, resistance is higher in the reverse direction, which helps maintain anteroposterior directional flow. We measured the contraction rate of the intestinal smooth muscle of *S. suckleyi*, and found that an average of 48 contractions is necessary for complete transit of a medium viscosity (20 Poise) substance. Finally, we provide the first 3D images of spiral intestines for *S. suckleyi*, *Dasyatis say*, *Rhinoptera bonasus*, and *Sphyrna tiburo*. These 3D reconstructions from CT scans of lyophylized spiral intestines provide a modern replacement for the heavily cited and revised Parker (1885) illustration. This investigation provides a new way of quantifying intestine volume, surface area created by the intestinal folds, and visualizing how flow may occur through the various spiral structures. It also provides a mechanism for the quantification of the functional morphology of the SI and opens the door to examining the function of the gastrointestinal tract of fishes and sharks.

P3.118 LEIGHTON, GM*; WANG, X; GUTENKUNST, RN; DORNHAUS, A; Cornell University, University of Arizona; *gml86@cornell.edu*

Delimiting Gene Expression Differences Between Behavioral Castes in Temnothorax rugatulus

A striking example of variation in cooperative behavior is the behavioral division of labor observed in many eusocial insect societies. A large volume of work has explored how division of labor may be organized; however, only recently has work begun explaining the physiological mechanisms that underlie differences in behavior between individuals in these societies. Many previous studies focus on differences between queens and workers, with few studies rigorously defining differences between workers. To elucidate gene expression differences between different behavioral castes, we used RNA-sequencing to measure expression in three groups of workers in the ant Temnothorax rugatulus. Using detailed behavioral observations we identified "foragers", "nurses", and "inactives". We collected individuals from each of these groups and performed RNA-sequencing on whole-body tissue, with two replicates. After quality control of sequences we retained a total of 270 million paired-end reads. We used the Trinity software package to build a reference transcriptome and aligned reads from each group to the reference. We then used the Trinity pipeline to identify genes that are differentially expressed between groups, and we employed pathway analysis to identify whether any pathways are enriched in certain groups. We find less differentiation in expression among groups than previous studies, and we compare our differentially expressed genes to other studies to determine if similar gene sets are used to promote similar behaviors. We then explore why we may not find strong similarities among other studies and suggest productive avenues for future research.

P2.161 LEISER-MILLER, LB*; SANTANA, SE; Univ. of Washington, Burke Museum; *leith1@uw.edu*

Morphological diversity in the sensory system of Neotropical Leaf-Nosed Bats (Chiroptera: Phyllostomidae), with implications for acoustic and dietary ecology.

The evolution of novel morphologies in the sensory system can lead to ecological diversification. Neotropical leaf-nosed bats (Phyllostomidae) are one of the most ecologically diverse groups of mammals, spanning a wide range of diets and foraging styles, and extreme morphological variation in external sensory structures used for echolocation (i.e., nose leaves and ears). To date, little is known about how morphological variation in these components of the sensory system evolve, and how they functionally affect echolocation parameters during foraging. We use phyllostomids as a model to address how the morphological diversity of external sensory structures influences ecological diversity. We applied 3D geometric morphometric analyses to quantify the shape of the nose leaf and ears of 19 phyllostomid species, spanning all the dietary guilds within the family (insectivory, animalivory, frugivory, nectarivory, omnivory and sanguinivory). We used these data to quantify how differences in sensory structure morphology are related to differences in echolocation call structure among species, and to test for relationships between morphological and dietary diversity. We found that different dietary guilds exhibit different amounts of diversity in the morphology of sensory structures and echolocation call parameters (e.g., maximum frequency and duration), with insectivorous and animalivorous bats exhibiting the greatest diversity. This may be explained by a lower prey type specificity, overall, in these guilds. Our results demonstrate that the morphology of the sensory system is tightly linked with acoustic and dietary diversity in bats.

P2.112 LEMASTER, MP*; LUTTERSCHMIDT, DI; Western Oregon Univ, OR, Portland State Univ, OR; *lemastm@wou.edu*

Estrogen Influences Pheromone Production in Garter Snakes

Male red-sided garter snakes (*Thamnophis sirtalis parietalis*) rely on a female sexual attractiveness pheromone to exhibit reproductive behavior during the breeding season. Prior research indicates that pheromone expression in the skin lipids of females occurs during winter dormancy and suggests a regulatory role for estrogen in this process. Here we present a study designed to parse out when in the dormancy period females begin to express the sexual attractiveness pheromone and to what extent estrogen may influence the timing of this event. To this end, we collected skin lipid extracts from female snakes during fall prehibernation and three time points during hibernation: 4, 8, and 16 weeks. At each time point, females were treated with either peanut oil (control) or estrogen for six days preceding skin lipid extraction. During the mating season, we then presented the samples to courting males using a Y-maze. Samples from each time period and treatment were presented in conjunction with skin lipid extracts from spring-collected, attractive females to determine whether males could differentiate between the two trail types. Results demonstrate that males prefer to follow trails from spring-collected females compared to peanut oil-treated females up through 4 weeks into winter dormancy, but lose the ability to discriminate between the two trail types once females have been in winter dormancy for 8 weeks. However, when presented with estrogen-treated female skin lipid trails, males lose the ability to discriminate between trail types after females have been in winter dormancy for only 4 weeks. These results suggest that pheromone expression begins during the second month in winter dormancy for female red-sided garter snakes, with the underlying mechanism becoming sensitive to estrogen within the first month.

117.6 LEMBERG, J.B.*; WESTNEAT, M.W.; SHUBIN, N.H.; University of Chicago; *lemberg@uchicago.edu*

Feeding mechanics of Atractosteus spatula: assessing the advantages of a mobile palate in a lateral-snapper

Gars provide valuable insight into the origins of plesiomorphic actinopterygian and osteichthyan feeding systems, but as rapid, lateral-snapping ambush predators, their own feeding system is highly derived. This study investigates the function of gar-specific specializations, such as horizontally-oriented palates, mobile pectoral girdles, and platyrostral skulls, that enable a surprising degree of cranial kinesis during feeding. To assess skull kinematics, we captured high-speed video of feeding in the alligator gar, *Atractosteus spatula*, and documented new anatomical features using contrast-enhanced computed tomography. This study reveals a system of coordinated interactions between the mandibular arch, hyoid arch, and pectoral girdle that produce rapid jaw movements and precisely timed buccal and pharyngeal expansions for the controlled movement of water. During a lateral strike, flat plate suction due to jaw opening and neurocranial elevation draws prey inward before hyoid depression begins. Hyoid depression is delayed by the line of action of the sternohyoideus and activity of the hyoid constrictors. The line of action of the sternohyoideus changes towards the conclusion of jaw opening due to neurocranial elevation and rotation of the pectoral girdle, resulting in pharyngeal expansion via hyoid depression, suspensorial abduction, and jaw adduction. This produces an anterior to poster flow of water during the feeding strike. Alligator gars demonstrate how a rapid, lateral-snapping feeding mechanism can utilize flat plate suction and delayed pharyngeal expansion to its advantage. These findings have implications for other platyrostral taxa, particularly fossil stem-tetrapods, that convergently evolved many similar morphological features as gars.

13.7 LENCER, E; Cornell University; *lencere@gmail.com*

Sources of Skull Variation Among ecologically Differentiated Species of Pupfish (Genus Cyprinodon(

Understanding the origins of novel phenotypic variation is fundamental to the study of biodiversity. Many studies have investigated the role of selection in driving phenotypic change, however equally important is how phenotypic variation is produced. The overarching goal of my thesis research is to understand the genetic and developmental sources of novel skull variation in a clade of three morphologically and trophically differentiated pupfish species (genus *Cyprinodon*) that co-occur on San Salvador Island, Bahamas. I am using RNA-seq to understand how modifications to gene expression vary among species at a transcriptomic level. These data are being used along with information about differences in growth rates of jaw elements to identify modifications to gene expression that may underlie the origins of ecologically critical phenotypes.

127.7 LENDVAI, AZ*; TOTH, Z; VINCZE, O; VAGASI, CI; PAP, PL; OUYANG, JQ; Univ. of Debrecen, Univ. Babes-Bolyai, Univ. of Nevada; *az.lendvai@gmail.com*

Insulin-Like Growth Factor-1 Decreases in Response to Stress in a Free-Living Bird

Insulin-like growth factor-1 (IGF-1) is an evolutionary conserved hormonal signal that regulates major life-history processes in all animals. Reduced IGF-1 signaling increases lifespan and the expression of genes involved in stress resistance in model organisms. However, it is unknown whether free-living organisms can adaptively respond to stressful stimuli by changing their IGF-1 levels. Here, we analyzed circulating IGF-1 levels in response to capture- restraint stress in a free-living songbird, the bearded reedling, *Panurus biarmicus*, a species characterized by an unusually fast life-history strategy. We found that IGF-1 levels significantly decreased compared to baseline levels even after 15 minutes of restraint, and this response showed marked individual and seasonal differences. Interestingly, the changes in IGF-1 levels were independent from the increase in glucocorticoid levels, which play a prominent role in the vertebrate stress response. Our results represent the first investigation of the effects of stress on IGF-1 levels in free-living organisms and suggest that the IGF-1 pathway can have an autonomous but important role in how individuals cope with environmental challenges.

P1.37 LENT, DD*; MENDOZA, A; AREVALO, E; Cal. State Univ., Fresno; *dlent@csufresno.edu*

Visual Cue Perception During the Establishment of an Ant's Foraging Route

A number of experiments have revealed how different visual features are used to guide familiar foraging routes in wood ants. Using these data, we have developed algorithms to extract visual features that ants use for guidance from panoramic scenes. In these experiments, we examine how the visual cues that ants use are extracted, prioritized and stored during navigation. A model was created to simulate navigation in a procedurally generated environment where the visual cues could be precisely characterized. In these environments, our algorithms extracted and stored the visual cues that were available during a single Levy walk foraging event. Following a random foraging event, the success on subsequent foraging bouts using the stored information was examined. In addition to the procedurally generated scenes, panoramic images from wooded areas, similar to the foraging terrain of our ants, were used to test our visual perception algorithms in natural scenes. Again, a single Levy walk was used to simulate the foraging route. The points of a Levy walk was generated in Matlab and these points determined the sites to be imaged. Following a single walk images were analyzed to identify and store the visual features. Our algorithms extracted several stable features that could be used to provide reliable landmarks to facilitate route learning. Following analysis and storage of the visual cues extracted from a natural scene, the success in finding the goal location on subsequent bouts was examined. These two studies have provided insight into how ants extract visual information from complex and natural scenes. This provided us with a platform to test predictions about the reliability and stability of specific visual features within complex, and cluttered panoramic scenes and has shown which cues may be stored to facilitate success on repeated foraging bouts.

97.5 LENTINK, D*; QUINN, D.B.; Stanford University; *dlentink@stanford.edu*

From quiet laminar flow to turbulent gusts: A new wind tunnel for studying animal flight performance and control

Our understanding of how animals fly has been greatly advanced by the development of specialized wind tunnels for animal flight. Existing world-class facilities can simulate flight conditions ranging from laminar flow and ascending versus descending flight to different atmospheric altitudes. However, the atmosphere in which animals fly is even more complex. Flow can be extraordinarily laminar and quiet at higher altitudes, while highly turbulent flow exists near the ground. To study how animals perform and control their flight in such diverse conditions, we developed a new closed-return wind tunnel for comparative biomechanics research. The flight chamber has exceptionally low noise and turbulence levels of 0.015%, which is closer to conditions at cruise altitude. An active turbulence generation system enables us to simulate turbulence intensities typical of near ground habitats for the first time. Furthermore, an open jet configuration enables stereo high-speed fluoroscopy for studying musculoskeletal control in the wind tunnel. Finally, the wind tunnel's wide speed range from 0 to 50 m/s, its exceptionally low turbulence and noise levels, as well as its remarkable velocity and temperature stability are ideal for studying the low Reynolds number aerodynamics of both flying animals and bio-inspired aerial robots.

19.2 LEON, AE*; HAWLEY, DM; Virginia Tech, Blacksburg; *leona@vt.edu*

Virulence and Within-Host Fitness of Mycoplasma gallisepticum in Previously Exposed House Finches

The host immune response can exert strong selective pressure on pathogen virulence, particularly when host immunity is incomplete. There have been few opportunities to test whether incomplete host immunity creates a within-host environment that favors higher pathogen virulence. In North American house finch populations, the bacterial pathogen *Mycoplasma gallisepticum* (MG) has increased in virulence since emerging in two geographically isolated populations. MG is an obligate parasite that is largely environmentally transmitted at bird feeders. Because MG is short-lived outside of the host, house finches are likely exposed to frequent low doses of pathogen while foraging at feeders. Previous work demonstrates that repeated exposure to low-doses of MG, a proxy for what birds likely experience while foraging, provides significant but incomplete protection against a high-dose homologous challenge. The aim of this experiment was to determine if this incomplete immunity produces a within-host environment that favors more virulent pathogen isolates. We manipulated prior exposure by giving MG-naïve house finches priming exposures that varied by dose and number of inoculations. After all animals were clinically healthy, individuals were given a challenge inoculation with one of three MG isolates ranging in virulence. The most virulent isolate had significantly higher pathogen fitness in hosts previously exposed to low levels of MG as compared to other isolates. A less virulent and a homologous isolate produced minimal infection loads with little or no disease in previously exposed hosts at all priming exposure levels. Our results indicate that previous low-level exposure to MG, which birds likely encounter at feeders, may produce a within-host environment that favors higher virulence.

88.2 LEPIANE, K L*; CLARK, C J; Univ of California, Riverside; *klepi001@ucr.edu*

The Evolution of Silent Flight in Owls

Silent flight is important to the hunting strategy of owls (Strigiformes). There are two hypotheses for why they evolved silent flight: stealth and masking. Under the stealth hypothesis, silent flight evolved as a means of ambushing unsuspecting prey, a strategy that is crucial to owls hunting prey that hear well, such as small mammals. Under the masking hypothesis, silent flight evolved to aid in prey detection, a strategy that is important to owls hunting by ear, e.g. at night or when prey has tunneled underneath snow. Specialized wing and feather features are hypothesized to be associated with silent flight. These features include the leading edge comb—modified barbs on the leading edge that give the wing a serrated appearance—and the trailing edge fringe—unconnected hook radiates at the trailing edge that create a frayed edge. We measured comb and fringe morphology on museum specimens of over 170 species of owl. We plotted wing and feather features on the owl phylogeny and examined the evolution of the leading edge comb and trailing edge fringe against ecological traits such as diet, foraging ecology, and body size. These wing features are highly variable and vary with prey type and active hours.

P1.30.5 LERI, J*; GRAHAM, Z; LADAGE, L; MCCORMICK, G; LANGKILDE, T; Pennsylvania State University - Altoona, Arizona State University, Pennsylvania State University; *johnleri@me.com*

Differential Contributions to Medial Cortex Volume in Eastern Fence Lizards Sceloporus Undulatus

The hippocampus, an area of the brain associated with memory and spatial processing, demonstrates a high degree of plasticity in attributes such as volume, neurogenesis, dendritic branching, and synaptic connections. Conventionally, hippocampal volume has been a convenient and non-invasive metric used to gage plasticity. However, the hippocampus is a non-homogenous structure with substructures that may be differentially modulated by environmental experiences. In particular, the reptilian hippocampal homologue, the medial cortex, exhibits substructures that vary dramatically in architecture; the cell layer is composed of tightly-packed neuronal soma while the inner and outer plexiform layers are primarily composed of neuronal and glial projections. In the current study, we utilized unbiased stereology to examine the relative contributions of the cell and plexiform layers to overall variation of the medial cortex in Eastern fence lizards (*Sceloporus undulatus*). We found that when overall medial cortex volume changed, the substructures did not proportionately contribute to those changes; the cell layer and inner plexiform layer increased while the outer plexiform layer did not. Further, changes in the cell layer were not attributable to variation in neuron soma size. Within the context of this study, these results suggest that substructures of the medial cortex do not vary proportionally and finer examination of substructures may be important in developing more precise hypotheses regarding the effects of environmental experiences on neural plasticity.

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Modeling spectral sensitivities of visual systems: identification of photoreceptor arrays using electroretinograms and multi-model inference

Understanding how individual photoreceptor cells factor in the spectral sensitivity of a visual system is essential to explain how they contribute to the visual ecology of the animal in question. Various methods that model the absorbance of visual pigments use templates which correspond closely to data from thin cross-sections of photoreceptor cells. However, few modeling approaches which compare optimized models incorporate physical parameters of real photoreceptors, which can be fused, and can form vertical tiers. Here, I employ Akaike's Information Criterion (AIC) to select absorptance models of multiple classes of photoreceptor cells that maximize information, given visual system spectral sensitivity data and histological parameters. This technique correctly selects among alternative models, and identifies between one and four spectral classes for the dark-acclimated visual systems of the velvet worm, *Principapillatus hitoyensis*, the branchiopod water flea, *Daphnia magna*, and humans. I also include data from the Asian swallowtail, *Papilio xuthus*, which has at least five main spectral photoreceptor classes in its compound eyes, to illustrate potential effects of model oversimplification on multi-model inference. This technique will be informative for future opsin expression studies and to support extracellular or intracellular electroretinography.

101.7 LEVESQUE, DL*; LANDRY-CUERRIER, M; LAROCQUE, G; MENZIES, A; MCGILL, BJ; HUMPHRIES, MM; Univ. of Maine, McGill Univ.; *danielle.l.levesque@maine.edu*

Embracing heterothermic diversity: an analytical approach for comparing and categorizing patterns of temperature variation in endotherms

Recent research is revealing incredible diversity in the thermoregulatory patterns of wild and captive endotherms. Classic thermoregulatory categories of ‘homeothermy', ‘daily heterothermy', and ‘hibernation' are becoming harder to delineate and understanding the physiological and evolutionary significance of variation within and around these categories is becoming more important. But we lack a generalized analytical approach for categorizing and comparing the nature of temperature variation expressed by individuals, populations, and species. Here we propose a new approach that decomposes body temperature time series into three inherent properties - wave form, amplitude, and period - using a non-stationary technique that accommodates temporal variation in form, amplitude and period. This approach quantifies circadian and seasonal variation in thermoregulatory patterns, and uses the distribution of observed thermoregulatory patterns as a basis for intra- and inter-specific comparisons. We analyse body temperature time series from multiple species, including classical hibernators, tropical heterotherms, and homeotherms, to highlight the approach's general usefulness and the major axes of thermoregulatory variation that it reveals.

113.3 LEVIN, E; MCCUE, M; DAVIDOWITZ, G*; University of Arizona, St. Mary's University; *goggy@email.arizona.edu*

Beyond sugar: allocation and metabolism of nectar amino acids and fatty acids in a Lepidopteran

Flower nectar is more than just water and sugar; it also contains other macro nutrients such as amino acids (AAs) and sometimes fatty acids (FAs). A previous study has suggested that AAs in nectar are not incorporated into eggs by Lepidoptera. Another study showed that carbon from nectar sucrose can be synthesized into non-essential AAs that are then allocated into eggs, whereas carbon from nectar sucrose is not incorporated into essential AAs, suggesting that essential AAs in lepidopteran eggs are derived solely from larval resources. Here we use a new technique of real-time respirometry coupled with real-time stable carbon isotope analysis to test the allocation and metabolic use of essential and non-essential AAs and FAs in the adult nectar diet to reproduction, adult flight muscle and adult metabolic fuel in female *Manduca sexta* hawk-moths. We used artificial nectar (25% sugar in water) enriched with one of the 13C-labeled essential AAs (leucine, phenylalanine) or non-essential AA (glycine), or one FA (palmitic acid). Our results show that both essential and non-essential AAs in the nectar diet are allocated to eggs, and can still be detected in 1st and 2nd instar larvae as well as in the adult flight muscle. Nectar FAs, however, were not allocated to either offspring or flight muscle, but were oxidized for energy by the adult at rest. Real-time measures show that nectar AAs and FAs are metabolized within minutes after feeding and continues for several hours. The ability to 13C-label specific AAs and FAs and track their metabolism in real time provides an abundance of opportunities to study macronutrient allocation in a diversity of organisms and life history contexts.

8.4 LEVY, T*; MANOR, R; TAMONE, SL; AFLALO, ED; SAGI, A; Ben-Gurion University of the Negev, Beer-Sheva, University of Alaska Southeast, Juneau; *toml@post.bgu.ac.il*

Sexual Differentiation during the Life History of a Protandric Shrimp

Crustacea is an ancient arthropod group which exhibits diverse types of reproductive strategies. Crustacean species whose reproduction type is deviated from the common gonochoristic scheme, such as the Northern spot shrimp *Pandalus platyceros*, present a unique opportunity for studying the controlling mechanism(s) behind sexual differentiation. *P. platyceros* is a protandric hermaphrodite decapod crustacean, native to the North Pacific Ocean, in which the three life stages occur consecutively: at early stage of life each animal functions as a male, then it exhibits a transitional stage followed by its transformation into a functional female. Given that each *P. platyceros* transforms from a functional male (producing sperm) to a functional female (producing eggs), this shrimp provides a model to study the changing morphology of the gonads and the role of the prominent masculine androgenic gland (AG) and the masculine insulin-like androgenic gland hormone (IAG) during its interesting life-cycle. In this study, *P. platyceros* specimens of the three developmental stages: male, transitional and female, were collected from Alaska. The gonads and the AG were characterized histologically in each stage. Moreover, the *IAG* gene was sequenced and its spatial and temporal expression described during the life history of the shrimp. Our results shed light on changes in the reproductive system, as well as the control of the masculine endocrine system during the shift from maleness to femaleness in a protandric species in which sexual differentiation is not limited to early developmental stages but occurs also during adulthood.

62.3 LEVY, O*; DAYAN, T; PORTER, WP; KRONFELD-SCHOR, N; Arizona State University, Tempe, Tel Aviv University, Tel Aviv, Israel, University of Wisconsin, Madison; *levyofi@gmail.com*

Time as an ecological resource: can diurnal animals compensate for climate change by nocturnal activity?

Considerable research is aimed at developing predictions of ecosystem responses to climate change, focusing on the spatial scale, such as range shifts and contractions, as well as activity restrictions to shaded microhabitats. On the other hand, the ability of species to shift their activity times at the diel scale and consequently to alter the environment in which their activity takes place is largely ignored. Here, we explored how shifts in activity patterns may buffer impacts of climate change. We simulated diurnal and nocturnal North American rodents and showed that future summers may decrease the energetic demands of nocturnal mammals while increasing water demands of diurnal mammals. Climatic projections suggest that vegetation cover and water availability will decrease under future climate, particularly when water demands are expected to increase the most, limiting the ability of diurnal animals to restrict activity to shaded microhabitats and to keep a positive water balance. Our analysis shows that by shifting to nocturnality, diurnal mammals may eliminate the high water costs of future summers. Future research should explore the role of the diel time axis as an ecological resource when predicting the impacts of climate change.

130.4 LEWIS, GT*; ZHU, R; ZHU, JZ; BART-SMITH, H; University of Virginia; *gtl6eh@virginia.edu*

The Influence of the Peduncle on Swimming Performance in Thunniform Swimmers

The peduncle of thunniform swimmers provides a region of interest when studying the swimming mechanism of these animals. The degree of freedom located there would seem to play a large role in influencing swimming performance, and we hypothesized that the rotation that the peduncle allows does significantly improve performance, as determined by metrics such as swimming speed, power consumption, and economy. Using a custom-built rig that replicates a free-swimming environment within a flow tank, we flapped biological samples of thunniform fins and flukes with the peduncle in both free and constrained conditions, while recording the data necessary to determine the above information, as well as high-resolution video. A comparison of the results shows improved performance from the rigid peduncle to the flexible and highlights the importance of the joint, particularly if the swimming mechanism is to be emulated. The video can aid in the reconstruction of the flow field using computational fluid dynamics, so that the improved performance can be understood on the most fundamental level.

35.6 LI, DH*; GILLY, WF; Hopkins Marine Station of Stanford University; *lidh@stanford.edu*

Effects of Hypoxia on Jet-Propelled Escape Behavior in Doryteuthis opalescens (California Market Squid)

Arguably the most athletic of marine invertebrates, squids can achieve a wide range of swimming speeds and maneuvers, including the powerful jet-propelled escape response. Underlying locomotion in many species of squid are two parallel motor-nerve pathways, the giant and non-giant axon systems, which can act individually or in concert to coordinate jetting. Because squids cannot thermoregulate and they have a high oxygen demand to sustain muscular activity, the maintenance of essential behaviors in the face of environmental variation poses a major challenge. *Doryteuthis opalescens* (California market squid) found in Monterey Bay often encounters intrusions of cold, hypoxic water from offshore, but effects of hypoxia on locomotion and its underlying mechanisms in this species remain unexplored. In this study, we elicited escape jets using a strobe-flash stimulus and recorded stellar nerve activity in conjunction with pressure inside the mantle cavity in restrained squid exposed to normoxic (>250 µmol/kg ≈ 8 mg/L) and acutely hypoxic (60 µmol/kg ≈ 2 mg/L) conditions at 8°C. Escape jet amplitude was lower and latency was longer under hypoxic conditions, but only for individuals that were exposed to hypoxia before normoxia. Squid exposed to normoxia followed by hypoxia did not show these differences, but they did show slightly increased latency and decreased jet amplitude upon return to normoxic conditions. The increase in latency and decrease in jet amplitude appear to coincide with a reduction in giant axon activity. These results suggest that exposure to hypoxia may primarily affect locomotor performance in *D. opalescens* by impairing giant axon activity.

43.5 LI, Y*; BERNARDINO, A.F.; HALANYCH, K.M.; Auburn University, Universidade Federal do Espírito Santo; *yzl0084@auburn.edu*

Recruitment patterns of deep-sea wood-boring bivalves (Xylophagidae, Mollusca) inferred from SNP data.

Wood falls occur widely in the deep-sea. They support specialized communities for limited periods of time and contribute fundamentally to biodiversity and contain evolutionary novelties. Wood-boring Xylophagidae are dominant species in deep-sea wood fall communities and play a key role in facilitating wood decomposition. Despite evolutionary and ecological importance of these obligate wood bores, very little is known of their distribution, dispersal potential, and recruitment sources. In this study, we deployed wood landers at two depths (1500 and 3000m), 250 km apart, in the NE Pacific and SW Atlantic basins. To evaluate connectivity and recruitment sources of these wood-boring bivalves, we then genotyped bivalves from 3 landers and a shallow water locality by using a 2b-RAD sequencing approach. We obtained ~ 2,000 filtered SNPs from 140 individuals collected in recovery wood landers after 13 months. Preliminary results suggested that genetic or species exchange was much greater within a depth zone than between different depth zones. Moreover, individuals of the bathyal site (~1500m) were most likely from the same recruitment source in each basin, whereas individuals living in abyssal site (~3000m) potentially came from different gene pools in NE Pacific.

77.3 LI, J.*; LEMER, S.; GIRIBET, G.; KIRKENDALE, L.; BIELER, R.; CAVANAUGH, C.; University of Colorado Boulder, Harvard University , Western Australian Museum, Field Museum of Natural History ; *jingchun.li@colorado.edu*

Seeing the Light: Evolution of Photosymbiosis in Marine Cockles

Photosymbiotic associations between invertebrate hosts and photosynthetic dinoflagellates are crucial to the trophic and structural integrity of tropical marine ecosystems. Although extensive efforts have been devoted to study the short-term ecological interactions between animal hosts and their symbionts, long-term evolutionary dynamics of photosymbiosis in many marine metazoans are less well understood. The marine bivalve family Cardiidae contains two lineages that include photosymbiotic taxa: the well-known giant clams (Subfamily Tridacninae) and the heart cockles (Subfamily Fraginae). Both groups host symbionts from the same genus (*Symbiodinium*), although several Fraginae species are non-symbiotic. To date, it is unclear whether the two bivalve lineages share a common photosymbiotic ancestor or evolved photosymbiosis independently. Morphologically, giant clams show relatively uniform shell forms whereas photosymbiotic taxa in the Fraginae exhibit a diverse suite of adaptations to photosymbiosis including greatly flattened, solar-panel-like shells and lens-like microstructural features. In this study, we established a backbone phylogeny for Cardiidae utilizing RNA-Seq-based transcriptomic data from five Tridacninae species, eight Fraginae taxa, and ten other cardiids. Phylogenomic approaches were used to resolve the relationship between Tridacninae and Fraginae, and to demonstrate how photosymbiosis evolved within the marine bivalve family Cardiidae. Our findings provide a solid foundation for understanding genomic evolution of photosymbiosis and long-term environmental influences (*e.g.,* climate change) on photosymbiotic marine communities.

98.6 LIBBY, T*; FULL, R.J.; Univ. of California, Berkeley; *tlibby@berkeley.edu*

Variable Limb Function Results in Similar Turning Behavior in Lizards.

Periodic steady-state locomotion like flat-ground walking and running typically display high stereotypy of forces and kinematics during limit-cycle behavior. We examined variability in an unsteady maneuver in lizards, *Agama agama*, during a prey-capture behavior where animals began from a standstill, turned and accelerated to catch prey delivered directly behind it. We expected these high-effort, time sensitive behaviors to exhibit strong stereotypy due to physical constraints (limits on muscle force, range of motion, and ground friction). To our surprise, we found that the sequence of footfalls and the pattern of limb forces varied widely, but resulted in similar task-level behavior (e.g. center-of-mass behavior). On average, agamas used a trot-like timing pattern over the entire behavior, but limbs varied in their functional role. Limbs could provide force to turn or accelerate the body, or both, depending on their location and timing of the step. The inside forelimb contributed least, but the other three limbs varied over similar ranges of linear (-10 to 60 mN*sec) and angular (-0.5 to 1.5 mN*m*sec) impulses, showing trade-offs. To further challenge the animals, we perturbed limb forces by reducing traction under one foot. Despite large slips of the foot, we found no significant difference in average time to complete the turn (350 ms to rotate 150°, even when a foot slipped more than 2 cm), showing that other limbs changed roles to compensate for the reduced effort of the perturbed limb. While steady state behaviors collapse to low dimension, we hypothesize that unsteady prey capture or escape maneuvers possess the capability to exploit a larger solution space to increase the robustness of the behavior.

P3.96 LIGOCKI, I/Y*; MAYTIN, A/K; UC Davis, Boston University; *iyligocki@ucdavis.edu*

Social Structure and Dominance Hierarchy Establishment in the Invasive Round Goby, Neogobius melanostomus

Organisms living at high densities may be forced to engage in conflict for access to resources such as food or shelter. When resources are limited, the outcome of agonistic interactions may have important fitness implications. We investigated the behavioral interactions of the invasive round goby (*Neogobius melanostomus*) in a shelter-limited environment. Round goby are benthic fish that utilize rocky shelters as reproductive sites where territorial males defend clutches of eggs. Previous work has shown that larger individuals have greater resource holding potential in dyadic interactions. In order to understand the outcome of agonistic interactions in more complex social environments, we observed same sex groups comprised of three differently sized individuals in an aquarium with limited access to shelters. We predicted that larger goby would behave aggressively towards smaller goby, and outcompete smaller goby for access to shelters. Because males defend shelters while breeding, we also predicted that male goby would compete more aggressively than females for possession of shelters. We found that the largest goby in each group behaved most aggressively towards all other individuals, and were also more often avoided by smaller conspecifics. This result was only true of the largest fish; the second largest and smallest fish were indistinguishable in terms of the counts of agonistic behaviors they performed or received in spite of comparable size differences. Overall, male goby behaved more aggressively towards same sex conspecifics than females. In spite of differences in aggressive behavior, larger goby did not spend more time inside shelters during the observation period. Our findings highlight that aspects of the social environment may limit the opportunity for individuals to establish dominance or ownership of resources.

P2.28 LIGUORI, AL; Stony Brook University; *alyssa.liguori@stonybrook.edu*

Multigenerational responses to lowered pH in the copepod Tigriopus californicus

Unprecedented increases in atmospheric carbon dioxide over the past century have resulted in a global reduction of seawater pH, or ocean acidification (OA). To date, the majority of studies on biological responses to OA involve short-term experiments where a single life stage is exposed to seawater chemistries predicted to occur in the future. Few studies address the influence of long-term acclimation and the potential for adaptive evolution to OA. I performed multigenerational experiments on the harpacticoid copepod *Tigriopus californicus* to investigate long-term responses to increased acidity. I collected copepods from supralittoral splash pools at four geographically isolated sites on San Juan Island, WA to maximize potential genetic variation in laboratory cultures. Reproductive F0 females from each population were allocated to three pH treatments: 8.0 (control), 7.5, and 7.0. To elucidate the effects of historic pH exposure on current performance, F1 reproductive females were split into three groups: one group kept in the same treatment and the other two groups transplanted into the other two treatments. The copepods were maintained in these treatments through the F2 generation (experimentation on subsequent generations is ongoing). For each generation and population, I quantified survivorship, fecundity, development time, and morphology. Preliminary data show that fecundity is reduced in the 7.0 pH treatment. This suggests that responses to low pH may involve changes in energetics and resource allocation. There seems to be no effect on adult survivorship, which is not surprising considering the extreme abiotic conditions in the splash pool habitats of *T. californicus*. Differences in responses among populations were also observed. Thus, there may be local adaptation to different environmental conditions within isolated habitats on San Juan Island.

107.7 LILLIS, A*; PANYI, A; MOONEY, TA; Woods Hole Oceanographic Institution, University of Southern Mississippi; *ashlee@whoi.edu*

Soundscape Engineers: Exploring The Drivers Of Snapping Behavior By Alpheid Shrimp And Their Influence On The Underwater Acoustic Environment

Soundscapes, the mixture of sounds that form the ambient acoustic environment, are increasingly recognized as a key influence on marine ecological pattern and process. Snapping shrimp (Alpheidae) are a diverse family of cryptic sound-producing crustaceans whose snaps dominate shallow-water marine soundscapes worldwide. Despite their outsized bio-acoustic contribution and probable influence on sound-mediated ecological processes, relatively little is known about snapping shrimp sound production patterns or the underlying behavioral ecology. Our recent efforts to sample habitat soundscapes at high spatiotemporal resolution have revealed complex dynamics in snapping shrimp sound production and suggest that snapping behaviors are not as simplistic as has been previously assumed. Snap rates generally exhibit diurnal and crepuscular rhythms, but these rhythms can vary over short spatial scales (e.g., opposite diurnal patterns between nearby reefs) and shift substantially over time (e.g., daytime versus nighttime dominance during different seasons). Snap rate variability relates to abiotic variables such as temperature, light, and DO, and biotic factors such as sex, size, and behavioral context. Our lab experiments using *Alpheus heterochaelis* indicate that snapping behavior likely serves multiple communicative functions and has high inter-individual variability. The nature of these relationships, underlying causal mechanisms, and impact on natural soundscapes under changing environmental conditions are beginning to be explored.

82.6 LIN, C*; CRONIN, TW; University of Maryland Baltimore County; *linc@umbc.edu*

Optic Lobe Metamorphosis in the Stomatopod Crustacean Alima pacifica

The compound eyes of stomatopod crustaceans have unusual ommatidial rows at the equator called the midband that are typically specialized for color and polarization vision. Beneath the retina, this midband specialization is also reflected in the brain, as distinct columns of midband neuropils and their projections can be traced throughout the optic lobe. We studied how this optic lobe morphologically changes from the larva with typical crustacean larval compound eyes, lacking a midband, to an adult with the midband in *Alima pacifica*. Before metamorphosis, late-stage larvae have double-retina eyes; the developing adult retina sits adjacent to the larval one. Using osmium-ethyl gallate staining, whole-mount immunolabeling, and 3D reconstruction, we show that photoreceptor axons from larval ommatidia project to a larval lamina split into two halves at the equator corresponding to the dorsal and ventral hemispheres of the adult. The halves supply axons to two components of a deeply curved larval medulla that join ventrally beneath the developing adult eye. Outputs from this larval medulla supply a bilobed larval lobula. Photoreceptors of the developing adult eye project to a new adult lamina, outputs of which subsequently supply a new adult medulla located above the joining point of the larval medulla. Axon fibers from this adult medulla pass through a groove in the larval medulla and supply a new adult lobula adjacent to the larval lobula. Our results reveal two independent visual processing pathways in the stomatopod optic lobe during metamorphosis. The adult system replaces the larval one about a week after metamorphosis, when the larval eye, together with its larval lamina, medulla and lobula, completely degenerates.

P3.41 LINDGREN, J/I*; ROUSE, G/W; Univ. of California, San Diego, Scripps Institution of Oceanography, UCSD; *johannairenelindgren@gmail.com*

Three new species of Branchipolynoe (Polynoidae, Annelida) from Costa Rican methane seeps

Aphroditiformia is a clade of annelids with over 1000 described species. Most scaleworms are free living, however many within Polynoidae are commensals with other animals. One genus, *Branchipolynoe*, currently contains three named species that are only found living commensally in mussels from hydrothermal vents and methane seeps. Three new species of *Branchipolynoe* were recently discovered from Pacific Costa Rican methane seeps. These newly discovered species live in three different species of *Bathymodiolus* mussels (also new) at depths from 1000 m to 1800 m. Two of the new *Branchipolynoe* species show specificity with single host mussel species. The third species occurs in two mussel species. Maximum likelihood phylogenetic analyses were performed on separate and concatenated CO1 and 16S data sets rooted with *Branchinotogluma*, a closely related genus of scaleworms. One new *Branchipolynoe* species is most closely related with *B. symmytilida*, the only named *Branchipolynoe* species from the East Pacific, while the other two species form a clade that is sister group to *Branchipolynoe* from the other side of the Panama Isthmus.

33.7 LIPSHUTZ, SE*; DERRYBERRY, EP; Tulane University; *slipshut@tulane.edu*

Genomic Characterization of a Hybrid Zone between Sex-role Reversed Jacanas

In several hybrid zones between species with male-dominant mating systems, male aggression drives genetic introgression into the less aggressive species. Sex-role-reversed systems, in which females compete for access to mates, provide a unique opportunity to investigate hybridization from a female perspective. We employ a hybrid zone between two sex-role reversed shorebird species, *Jacana spinosa* and *Jacana jacana*, to examine the role of female competition in hybridization. In a previous study, mitochondrial DNA (mtDNA) sequences revealed an asymmetry of introgression - hybrids share their mtDNA haplotypes with *J. spinosa*, but not *J. jacana*. Geographic clinal analyses suggested that mtDNA haplotypes show reduced introgression relative to autosomal markers, a pattern typically interpreted as an indication of Haldane's Rule, i.e. reduced fitness in the heterogametic sex, which are females in birds. Aggression assays revealed that *J. spinosa* females are more aggressive than *J. jacana* females, which could allow them to outcompete *J. spinosa* females for territories in the hybrid zone. In this study, we investigate whether asymmetrical introgression is related to the competitive dominance of *J. spinosa* females, or a consequence of hybrid inviability. To test for female-mediated asymmetric introgression across the hybrid zone, we conducted geographic cline analyses comparing a sub-genomic dataset of ~43,000 SNPS with traits related to the female competitive phenotype. We find that the behavioral processes mediating hybridization between sex-role reversed species are similar to those with dominant-male sex roles, but that role-reversed females may face higher postzygotic selection pressures than traditional-role males in the context of avian hybridization.

101.1 LISOVSKI, S*; RAMENOFSKY, M; WINGFIELD, JC; Univ. of California, Davis; *simeon.lisovski@gmail.com*

Biologically Significant Dimensions of Seasonality

The combined effects of the earth's tilt and rotation result in geographically divergent annual variations in solar radiation ensuing concomitant global variations in seasonal climates. For example, the tundra regions are characterized by biological productivity that is confined to the brief summer. On the other hand, the temperate-deciduous forests exhibit high annual seasonal variations in productivity of all terrestrial ecosystems. As another extreme, the tropical rainforests often experience weak seasonality with only modest variations in annual temperature and rainfall. These geographic variations in seasonal dynamics underpin the evolution of the earth's diverse biomes as well as key biological processes such as reproduction, predator-prey interactions, host-pathogen dynamics and the impressive annual migrations by billions of animals. However, seasonality is hard to quantify given its multidimensionality. The start of the season is arguably the most commonly used metric to describe the effect of seasonality on the physiology and behaviour of organisms and how changes induced by climate change and habitat alterations affect this interaction. But the start of the season is just one of several yet underappreciated dimensions of seasonality that includes duration, intensity of the annual change, velocity (how quickly those changes occur). Furthermore, seasonality can be characterised based on climatic features or on the concomitant response of the ecosystem including varying degrees of predictability. Here, we aim to introduce a holistic view of seasonality and its biologically important dimensions and put them in context of physiological adaptations, neural and hormonal control mechanisms, and how changes in seasonality may affect the capacity of organism to cope with change.

P2.33 LITCHFIELD, JE; TOBALSKE, BW; POWERS, SD*; POWERS, DR; George Fox Univ., Newberg, OR, Univ. of Montana, Missoula; *seandpowers@gmail.com*

Do Near-Field Changes in Surface Temperature Provide Evidence for Physiological Control of Heat Dissipation During Flight in Hummingbirds?

As global temperatures increase, hummingbirds must be able to dissipate excess heat produced during flight to avoid hyperthermia. In birds, heat dissipation during flight is retarded by feathers, which cover most body surfaces. Heat dissipation is critical for hummingbirds who generate enormous mass-specific power during hovering. The heat dissipation area surrounding the eye is particularly important because of high near-field flow velocities generated around the head. In this study we made near-field measurements of surface temperature around the eye of calliope hummingbirds (*Selasphorus calliope*; ~2.7 g) to look for evidence of physiological regulation of heat delivery in response to increased heat production during flight. Average surface temperature of the heat dissipation area was 30.3°C, and did not vary with flight speed. During hovering, the maximum surface temperature increased by 0.2 °C during an ~8 second interval. At flight speeds of 4 and 8 m/s, the maximum surface temperature decreased by 0.1-0.2°C due to increased convection. At 8 m/s maximum surface temperature decreased 0.6 °C, and size of the heat dissipation area decreased by 33%. The small increase in maximum surface temperature during hovering might indicate increased heat delivery to the skin surface. Any evidence of increased heat delivery during forward flight is likely masked by increased convection.

P1.136 LITWA, HP*; TINDLE, KC; FASANELLO, VJ; GEDULDIG, JE; TRICOLA, GM; PAITZ, RT; HAUSSMANN, MF; Bucknell Univ., Illinois State Univ.; *hpl002@bucknell.edu*

An acute rise in glucocorticoids reduces antioxidant levels and contributes to oxidative stress in Japanese quail (Coturnix japonica)

Oxidative stress, a central mechanism in the aging process, occurs when the production of damaging reactive oxygen species exceeds the ability of antioxidant defense to neutralize these unstable molecules. While it is known that chronic glucocorticoid exposure can increase oxidative stress levels (Glucocorticoid-induced Oxidative Stress), less is understood about how an acute rise in glucocorticoids affects oxidative stress. Recent work from our laboratory has reported that an increase in oxidative stress follows an acute stress response, but whether this is specifically due to increased glucocorticoids remains unclear. We fed Japanese quail (*Coturnix japonica*) mealworms injected with either corticosterone (CORT quail), the main avian glucocorticoid, or sesame oil (control quail) to determine if corticosterone was responsible for the rise in oxidative stress during an acute stress response. Forty-five min post-ingestion we collected blood samples to measure total antioxidant capacity (TAC) and reactive oxygen metabolites (ROMs). We found that CORT quail had higher plasma corticosterone concentrations 10min post-ingestion compared to control quail. However, while plasma corticosterone levels returned to baseline by 45min in both CORT and control quail, TAC levels were reduced at this time in the CORT compared to the control quail. Plasma ROMs levels did not differ between treatment groups. Lower TAC levels following corticosterone ingestion suggests that acute increases in corticosterone contribute to oxidative stress during an acute stress response.

P1.24 LOCKE, SJ*; THOMAS, RI; WATSON, WH; NEWCOMB, JM; New England College, University of New Hampshire; *slocke_ug@nec.edu*

Localization of Circadian Clock Proteins in the Nervous System of the Mollusk Melibe leonina

Circadian rhythms are controlled by a set of clock genes which include *clock, period, cryptochrome 1 (cry1),* and *cryptochrome 2 (cry2)*. The protein sequences for these circadian genes have been previously determined for the mollusk *Melibe leonina*, which expresses circadian rhythms of locomotion. These protein sequences were used for the development of custom antibodies, which were used in this study. CLOCK immunoreactivity was consistently seen in 10 neurons, located in the buccal and cerebropleural ganglia. PERIOD immunoreactivity was observed in 6 neurons in the cerebropleural and pedal ganglia. Two neurons near the midline of the cerebropleural ganglia exhibited CRY1 immunoreactivity, and these cells also co-localized with CLOCK. Together, results from these custom antibodies are beginning to elucidate the putative circadian clock in *Melibe*.

87.6 LOCKWOOD, BL*; GUPTA, T; University of Vermont; *Brent.Lockwood@uvm.edu*

Molecular targets of thermal stress during early development in Drosophila melanogaster

The effects of temperature on physiological processes are ubiquitous. However, to a large extent, the effects of thermal stress on developmental processes during early life stages have not been characterized. We employed high-resolution confocal microscope imaging to examine early embryonic development across ecologically relevant thermal gradients in *Drosophila melanogaster*. We quantified changes in the actin cytoskeleton, using a fractal dimension modeling framework, and we found that high temperatures induced significant disruptions to the actin cytoskeleton, which is the major molecular driver of early development. These changes were coupled with generalized protein aggregation and activation of the unfolded protein response (UPR) within the maternally-derived endoplasmic reticulum (ER). As *Drosophila* embryos routinely experience such thermal fluctuations during development, these results provide a mechanistic framework with which to explore thermal constraints that may shape the evolution of spatiotemporally-restricted egg laying rhythms, as well as the limits of physiological plasticity during early development.

5.2 LOGAN, ML*; MINNAAR, IA; CLUSELLA-TRULLAS, S; Harvard University, Stellenbosch University; *mike.logan1983@gmail.com*

The evolutionary potential of a global insect invader in the face of rapid environmental change

Anthropogenic climate change and invasive species represent two of the most feared threats to our planet's biodiversity. Typically, these stressors are studied in isolation, but their interaction may profoundly impact native species in unanticipated ways. For example, invasive species by definition have successfully adapted to novel environments, and may therefore be particularly resilient to future environmental change. Climate change, then, may tip the balance in favor of invasive species over the native species with whom they compete. We examined the evolutionary potential of the harlequin ladybug (*Harmonia axyridis*), a predatory, globally-invasive beetle that competes with native species in South Africa and elsewhere. We measured the thermal sensitivity of walking speed in over 500 third generation captive-reared individuals and estimated the genetic architecture (heritabilities and genetic correlations) of parameters that define the shape of the thermal performance curve. We discuss the implications of our results for competitive interactions between *H. axyridis* and native beetles as the climate in South Africa continues to become hotter and drier. More generally, we discuss the role of evolutionary adaptation in facilitating invasion and changing the competitive dynamics between native and alien species around the globe.

P3.169 LOGAN, L*; FREDERICH, M; Univ. of New England, Biddeford; *llogan@une.edu*

Differential behavior, habitat destruction, and stress tolerance in three populations of Carcinus maenas

The green crab, *Carcinus maenas*, is a globally invasive species native to Europe. It was introduced to the Eastern US in the early 1800's and then to Nova Scotia and Prince Edward Island in the 1980's. This led to genetically different populations of green crabs on the east coast of North America. Our project investigates population specific differences in stress physiology, behavior, and habitat destruction. Crabs were collected in Maine (ME), Nova Scotia (NS), and Newfoundland (NF) and incubated at 3, 8, and 16ºC, and at 12, 34, and 40 ppt for 48 hours. Gene and protein expression of HSP70, AMPK, and Na^+-K^+-$2Cl^-$-cotransporter was measured in heart, chelae, gill, and hepatopancreas tissue. We also measured aggression, righting response, and treadmill running endurance. To assess damage to seagrass habitat from the animals, crabs were placed in a 5 m diameter mesocosm that contained 3 different densities of *Zostera marina*. Location of the crabs within the tank was quantified over 3 days by daily observations and Z. marina damage was evaluated for frayed blades, and uprooted plants. First results show that crabs from NF spent more time above the sediment than those from ME, which can lead to more seagrass disruption, while above the sediment the crabs from ME are more destructive to *Z. marina*. Crabs from NS were more aggressive than ME and NF populations at all temperatures. At 3ºC NS crabs were the least active on the treadmill. The NF crabs were consistently more active on the treadmill at 3ºC. Ongoing analyses of the tissue samples will show whether the observed behavioral differences are mirrored in cellular and molecular stress parameters. A mechanistic understanding of the population-specific tolerance and behavior is crucial for predicting potential future invasions of this species.

P1.255 LOHMANN, AC*; HEDRICK, TL; Univ. of North Carolina at Chapel Hill; *alohmann@live.unc.edu*

Intra and interspecific chase dynamics in wild, freely behaving dragonflies

Pursuit and interception are common behaviors that engage many aspects of locomotor biomechanics, sensory physiology and neural processing. Dragonflies are a well-studied system for prey interception, with a number of different studies examining response latencies and interception algorithms from sit-and-wait species in controlled environments. However, dragonflies also engage in intra and interspecific interactions as part of mating and territory defense and the dynamics of these interactions are less well known. We use a newly developed camera-based mobile 3D videography system to record chases and interactions of several dragonfly species including *Libellula luctuosa*, *Libellula vibrans*, and *Perithemis tenera* in natural environments near Chapel Hill, NC. From the resulting trajectories we quantified the response dynamics, hypothesizing that the interception or tracking algorithms match those used for prey species, but that response latencies would tend to be larger to reduce the possibility of deceptive maneuvers by a target with near-equivalent flight performance capabilities to the pursuer, consistent with analysis of intraspecific chases in barn swallows. Contrary to these expectations, preliminary results show that response latencies based on whole animal trajectories were ~17 ms, less than the ~33 ms reported for predatory tracking and interception, albeit in a different dragonfly species studied in an enclosed environment. Trajectory kinematics were consistent with pursuit and constant bearing tracking, with shifts to a new constant each time the pursued dragonfly made an evasive maneuver and was re-detected by the pursuer. Flight speeds exceeded 8 m s^{-1}, and centripetal forces exceeded 5 body weights.

108.6 LOHMANN, KJ*; ENDRES, CS; PUTMAN, NF; ERNST, DA; LOHMANN, CMF; Univ. North Carolina, Chapel Hill, Univ. Miami; *KLohmann@email.unc.edu*

Natal Homing and Multi-modal Navigation in Sea Turtles and Salmon

Sea turtles and salmon are iconic long-distance ocean migrants with extraordinary navigational abilities. Both groups of animals have been hypothesized to complete long-distance reproductive migrations by sequentially using two different suites of mechanisms, each of which functions over a different spatial scale. For salmon, evidence indicates that magnetic cues guide fish into the vicinity of their home rivers, after which olfactory cues lead them upstream to the spawning grounds. For sea turtles, individuals that nest on continental coastlines may be able to reach nesting areas using magnetic cues alone, but for those that nest on small, remote islands, the gradual change in Earth's magnetic field probably precludes relying exclusively on magnetic navigation. An interesting example involves green turtles that nest on Ascension Island, a tiny land mass located 2000 km from the turtles' foraging grounds along the coast of Brazil. One possibility is that turtles use magnetic cues to arrive in the vicinity of the island, then use olfactory cues to pinpoint its location. To investigate, we used oceanic, atmospheric, and geomagnetic models to assess whether magnetic and chemical cues might plausibly be used by turtles to locate Ascension Island. Results suggest that either cue alone is unlikely to enable turtles to reach the island, but using the two together can potentially provide a successful navigational strategy. These findings are consistent with the hypothesis that sea turtles, and perhaps other marine animals, use a multi-modal navigational strategy when migrating long distances to remote islands.

27.2 LOLAVAR, A*; WYNEKEN, J; ERB, T; Florida Atlantic University; *alolavar@fau.edu*

Impacts of climate change on sea turtle development

Sex in many reptiles is environmentally determined, primarily by temperature during incubation. For this reason, the thermal effects with climate changes are predicted to have profound effects on sex ratios. However, predictions of future thermal effects are largely based on proxies that vary greatly in their robustness. Historic weather data, sea surface temperatures, and sand temperatures have been used to estimate past or future nest and rookery sex ratios. Estimates of sex ratios from proxies are rarely verified so their predictive potential is questionable. Currently, climate change predictions do not include potential impacts of other changing environmental variables. Here we examine the effects of changing nest moisture (precipitation). Predictions by the various climate change models do not account for other developmental and morphological consequences that could impact current and future populations. We present a case study that examines the potential effects of temperature and precipitation changes on future populations. Experimental laboratory studies aid our understanding of previously under-appreciated environmental effects. We identify thermal and hydric effects on sea turtle development, sex determination, and morphology such as hatchling size and growth rate, which ultimately affect hatchling survival.

P1.274 LOMAX, JJ*; BRAINERD, EL; Brown University; *jeremy_lomax@brown.edu*

Investigating the potential contribution of the sternohyoid muscle to suction power production in striped surfperch, Embiotoca lateralis

In ray-finned fishes, the sternohyoid (SH) is amongst the largest of the cranial muscles and from its size should contribute to the overall power required for suction feeding. In largemouth bass (*Micropterus salmoides*) however, the SH makes little to no power contribution as it does not shorten during suction expansion, a requirement for power production. The SH muscle in largemouth bass is relatively small, representing less than 2% of the cranial and axial muscle mass responsible for producing necessary power. For comparison with largemouth bass, we studied a single species, the striped surfperch (*Embiotoca lateralis*), in which the SH is 8% of the active muscle mass, to determine the possibility SH contribution to suction power. We measured muscle strain in the SH, epaxial, and hypaxial muscles with external markers attached to the skin, as the skin is tightly connected to the underlying muscles. Suction feeding was recorded with two high speed video cameras (500-1000 frames/s) calibrated with a Lego calibration object. We tracked the markers and calculated 3D coordinates with XMALab software (n=18 strikes from 3 individuals). We found that the SH shortened by a mean of 9.5% during suction expansion in the striped surfperch. The mean peak velocity of shortening was 5.4 lengths/sec, which is near the optimal velocity for power production in fish white muscle. We conclude that the sternohyoid is not only capable, but also likely to contribute to overall expansion power in *Embiotoca lateralis*, though further study is necessary to determine to what extent.

57.3 LONG, S. M.*; JAKOB, E. M.; University of Arizona, University of Massachusetts; *skye.m.long@gmail.com*

Variation in Morphology and Organization of the Secondary Eye Optic Neuropils Across the Order of Araneae

Although the relationship between behavior and the brain is well studied in insects, the brains of only a few of the some 40,000 spider species have been described and comparative studies of spider brain morphology are limited in scope. The current project uses a novel histological technique that allows for the rapid processing and imaging of whole spider cephalothoraxes. This approach improves our ability to accurately measure brain regions and places the brain within the context of other tissues, giving a more holistic view of spider neuromorphology. Nineteen species sampled from across the Araneae show striking variation in general brain morphology and the size of different brain regions. In particular, the organization and morphology of the visual processing pathway of the secondary eyes show four distinct conditions. These conditions vary both in the number of pre-protocerebral optic neuropils and in the connectivity pathways between the secondary eye retinas and nerve tracts in the protocerebrum. The current study highlights the vast amount of variation found in spider neuromorphology and the potential for using brain variation to study visual processing in spiders.

P1.218 LONG, JH*; EWOLDT, R; PORTER, ME; Vassar College, Univ. of Illinois, Urbana-Champaign, Florida Atlantic Univ.; *jolong@vassar.edu*

Morphological Computation: Adjustable Mechanical Control in Structures with Non-linear Viscoelasticity

Embodiment theory for mobile agents proposes that the behavior of animals is controlled, in part, by morphological computation, the physical interaction of the body and the environment. How might this non-neural control system operate to adjust to changing mechanical loads? We propose that for rhythmic or transient behaviors, such as cruising and escaping in fish, functionally important changes in the mechanical properties of a structure can and do occur within a single cycle. The framework of non-linear viscoelasticity (NLV) provides both the analytical methods and the functional models for understanding these changes. We modified Ewoldt's Large Amplitude Oscillatory Shear approach, originally created for rheology, to work with structural systems in bending. We bend vertebral columns of sharks, identify non-linear features as harmonics of fundamental properties, and model a frequency-curvature space that proposes alternating spring and brake functions for the structure within a single tailbeat.

126.5 LONGO, SJ*; WAINWRIGHT, PC; University of California, Davis; *sjlongo@ucdavis.edu*

A Combination of Biomechanical Factors Constrains Craniofacial Diversity in Seahorses and Pipefishes

A combination of extreme morphological and functional specializations in seahorses and pipefishes (Syngnathidae) makes them a compelling system to study how complex structure-function relationships evolve and feed back into the morphological evolution of organisms. Syngnathids possess an elongated snout, which they use in a modified form of prey capture whereby rapid dorsal head rotation brings the mouth close to prey. In addition, it has been shown that they power amplify their strikes, which allows seahorses and pipefish to approach prey exceptionally quickly. In these fishes it has been previously predicted that snout length should trade off with snout cross-sectional area to minimize inertial forces during rotation. However, drag forces on the snout can also be significant during head rotation, and may be minimized as well, which would primarily effect snout width and length. We tested these predictions in a phylogenetic context using a newly constructed phylogeny in combination with a dataset of linear measurements of 50 species of syngnathids. Phylogenetic regression and model-based comparative methods were used to investigate the relationships and relative rates of snout width, depth, length and area. We find that snout cross-sectional area does trade-off with snout length even when phylogeny is taken into account, but this relationship is largely driven by constraints on snout width: snout width and not depth is correlated with snout length, and snout width has much slower (20x slower) rates of morphological diversification compared to snout depth. Our interpretation is that the joint effects of drag and inertial forces constrain snout shape diversity in syngnathids.

74.6 LONGO, AV*; ZAMUDIO, KR; University of Maryland and Smithsonian Institution, Cornell University; *avlongo@umd.edu*

Environmental fluctuations and host skin bacteria shift survival advantage between frogs and their fungal pathogen

Fluctuating environments can modulate host-pathogen interactions by providing a temporary advantage to one of the interacting organisms. However, we know very little about how environmental conditions facilitate beneficial interactions between hosts and their microbial communities, resulting in individual persistence with a particular pathogen. Here, we experimentally infected *Eleutherodactylus coqui* frogs with the fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*) under environmental conditions known to confer the survival advantage to the host during the warm-wet season, or alternatively to the pathogen during the cool-dry season. We used 16S rRNA amplicon sequencing to quantify changes in bacterial richness and phylogenetic diversity, and identified OTUs that became overrepresented or suppressed as a consequence of *Bd* infection. During the warm-wet season, frogs limited *Bd* infections, recruited putatively beneficial bacteria, and returned to pre-infection levels of richness and phylogenetic diversity. In contrast, during the cool-dry season, *Bd* infections kept increasing through time, and bacterial diversity remained constant. Our findings confirm that infection outcome not only depends on abiotic factors, but also on biotic interactions between hosts and their associated bacterial communities.

40.4 LONTHAIR, JK*; HWANG, PP; ESBAUGH, AJ; University of Texas Marine Science Institute, Academia Sinica; *jlonthair@utexas.edu*

Impacts of elevated CO_2 exposure to early life stages of two estuarine species with differing life histories

It is theorized that ocean acidification (OA) will have significantly higher impacts on early life stages teleost due to their lack of well-developed acid-base machinery. Estuaries are dynamic environments that undergo fluctuations in environmental parameters. Specifically, we have documented changes in pH over daily, seasonal, and yearly time scales. This led us to believe that estuaries may be a source of resilient genotypes for OA. Here we provide evidence of resilience of two different estuarine species with different life histories. *Sciaenops ocellatus*, which are native to the West Atlantic and Caribbean, are fast developing and are rapidly integrated into the estuarine environment. *Epinephelus coioides*, which are native to the Indo-West Pacific, are also fast developing but have a delayed integration into the estuarine environment. We hypothesized that due to the delayed migration into the estuary that early life stage *E. coioides* would be more severely impacted by increases in CO_2 exposure, while *S. ocellatus* would be more resilient. Our results indicate that both species are resilient to OA. We observed no alteration to survival, length, and yolk size at increased exposure in *E. coioides*, but we did observe a significant increase in heart rate at 3000 µatm. Similar patterns were observed in *S. ocellatus*, with no significant change in length and yolk depletion rate, but a significant change in heart rate and survival at 3000 µatm. This tolerance may be related to early induction of acid-base balance pathways as gene expression of major acid-base transporters peaks at 16 hours post-fertilization for *S. ocellatus*, which is coincident with the presence of epithelial ionocytes.

28.7 LOPANIK, NB*; MATHEW, M; BEAN, KI; Georgia Inst. of Technology, Georgia State University; *nicole.lopanik@eas.gatech.edu*

Impacts of symbiont-produced natural products on host fitness

The colonial marine bryozoan *Bugula neritina* hosts an uncultured microbial symbiont that produces bioactive natural products, the bryostatins. These compounds have been shown to be ecologically relevant as they are unpalatable and deter predation on the host's vulnerable larvae. Bryostatins are potent activators of some forms of protein kinase C (PKC), a eukaryotic signaling protein involved in many cellular processes. We observed that hosts with reduced symbiont-titers (both naturally and through antibiotic curing) had decreased fecundity compared to colonies with normal symbiont loads, suggesting that host reproduction may be dependent on the presence of the symbiont and/or symbiont-produced bryostatins. Western blot analysis indicated that bryostatin-activated PKC expression in hosts with normal symbiont titers was different from that in hosts with reduced symbiont loads. In contrast, expression of PKC forms that are not activated by bryostatins was not different in the two forms of the colonies. Taken together, this suggests that the symbiont-produced bryostatins affect the host cellular biochemistry. Host transcriptome sequencing revealed the presence of 5 PKC isoforms. Sequence analysis suggests that the isoforms from *B. neritina* may have different amino acid residues that could result in differing bryostatin binding affinities. As PKCs can play an important role in the regulation of reproductive processes, we suggest that the host may utilize the presence of symbiont-produced bioactive bryostatins as a cue for reproduction via PKC activation.

P2.267 LOPEZ-CERON, A*; MUDRON, M; MYKLES, D; Colorado State University; *alopcer@rams.colostate.edu*

Molecular Response to Environmental Stressors in the Y-Organ of Carcinus Maenas

Carcinus maenas, an intertidal species, faces daily variations of temperature and oxygen. Molecular pathways involved in stress response include genes expressed following energy depletion, hypoxia, and heat shock. Sirtuin stabilizes many transcription factors by deacetylation. High AMP:ATP ratio down regulates mTOR via AMP kinase (AMPk) to conserve cellular energy. Hypoxia triggers HIF transcription and upregulates hypoxia-sensitive genes. At elevated temperatures, HSP's act as molecular chaperones to protect cellular proteins. Crabs shifted from ~14 ˚C to temperatures between 5 and 30 °C for 1 or 2 h. Also, green crabs were exposed to emersion-induced hypoxia ± desiccation for 2, 4, and 6 h. The responses of were determined using mRNA levels of AMPk, mTOR, Rheb, HIF, HSP70, and SIRT were used determine the responses of Y-organ, gill, heart, skeletal muscle, eyestalk ganglia (ESG), and thoracic ganglion (TG). *C. maenas* tolerated a wide temperature range, requiring 2-h exposures at 5 °C and 30 °C to affect gene expression. HSP70 increased in all tissues at 30 ˚C. Emersion alone had little or no effect on gene expression. Combined emersion/desiccation stress decreased gene expression by 6 h in heart and gill. In summary, high temperature and emersion with desiccation time upregulates AMPk and SIRT, downregulates mTOR, which would repress translation by relocating energy. Tissue response varied, with gill and heart more sensitive to stress than other tissues. Supported by NSF (IOS-1257732).

P2.260 LOPPNOW, TN*; SILLIMAN, RA; CHAMPAGNE, AM; DELONEY-MARINO, CR; University of Southern Indiana; *tnloppnow@eagles.usi.edu*

Effect of seasonal changes on antimicrobial defenses in the avian stratum corneum II: Antimicrobial activity in lipids

The stratum corneum (SC) is the most superficial layer of skin, and is composed of several layers of flattened dead cells called corneocytes embedded in a lipid matrix. These lipids are known to play a critical role in regulating cutaneous water loss. However, these lipids may also play a role in regulating bacterial composition of the SC, as many lipids exhibit antimicrobial activity. In this study, we assessed the antimicrobial activity of lipid extracts of known composition taken from the SC of House Sparrows (*Passer domesticus*). We used bacterial assays to measure minimum inhibitory concentration (MIC) of these lipids against several species of bacteria common on the avian epidermis including *Staphylococcus aureus*, *Escherichia coli*, and *Bacillus licheniformis*. We found that the antimicrobial activity of lipids depends on fatty acid composition and the target bacteria. Our results clarify the role of lipids in regulating bacterial community composition on bird skin.

P2.141 LOUBRIEL GRAJALES, D*; JOHNSON, M; NIEDZIALEK, O; PEREZ TORRES, M; MELENDEZ, A; ALEMAN RIOS , J; MOSIER, A; ABRAMSON, C; GIRAY, T; BARTHELL, J; GONZALEZ, V; AGOSTO RIVERA, J; University of Puerto Rico at Rio Piedras, Dickinson College, Bard College, Oklahoma State University, University of Central Oklahoma, University of Kansas; *darimarmilagros@gmail.com*

Analysis of Convolvulaceae Circadian Rhythm and Systropha Visitation Rates

Spiral-horned bees belong to the genus *Systroph*a and are morphologically and biologically interesting organisms. Based on previous data, one can hypothesize a strong association of *Systropha* with *Convolvulaceae* because *Systropha* are thought to be oligolectic on *Convolvulaceae* flowers, mainly on species of *Convolvulus* with tricolporate pollen grains. However, despite these morphological divergences in the host plants, the available data suggest an association between *Systropha* and *Convolvulaceae* flowers. The comparison between *Systropha* and *Convolvulaceae* is studied to understand the circadian rhythm of *Systropha*. Five 1 x 1 meter patches of *Convolvulus* were selected at Namık Kemal Üniversitesi in Tekirdağ, Turkey. The visitation numbers of four categories of bees, *Systropha planidens*, *Systropha curvicornis*, *Apis mellifera*, and "other bees", were recorded in each quadrat for two minutes. Although *Convolvulus* opened at approximately 7:00 and closed by 14:00, the nectar levels occurred in a smaller time frame, peaking at 8:00 and zeroing approximately at 11:00. *Systropha* exhibited peak visitation levels that lasted from approximately 9:00 to 11:00. This finding suggests that closing time is determined by another environmental factor or by the intrinsic clock of the flower. Meanwhile, the peak of *Apis mellifera* visitations varied on each day of the study. The early visitation time of *Systropha* may be to avoid competition with other bees for the nectar from *Convolvulus*. We can infer that light intensity is an influential factor in *Convolvulaceae* rhythmic behavior.

92.3 LOUDER, MIM*; BREWER, MS; SPOTTISWOODE, CN; SORENSON, MD; HAUBER, ME; BALAKRISHNAN, CN; East Carolina University, University of Cambridge, Boston University, City University of New York; *mckimlouder@gmail.com*

Genetic basis for convergent evolution of a complex behavior: insights from avian brood parasites

Little is known about the genetic changes that enable convergent shifts in social behavior across diverse taxonomic lineages. Obligate avian brood parasitism, in which birds lay eggs in other species' nests and rely on the 'host' for parental care, has evolved independently seven times in distinct lineages. This repeated loss of parental care provides a unique opportunity to reveal the molecular mechanisms responsible for the convergent evolution of behavior. To identify genes that evolved under positive selection among brood parasite lineages, we generated high coverage (> 30x) whole-genome sequences in four brood parasitic species from two distinct songbird lineages (molothrine cowbirds and viduid finches) as well as two non-parasitic relatives. Using selection tests for coding sequences (PAML), we compared over 9000 orthologous genes between brood parasites and non-parasitic songbird species. Both the cowbird and viduid finch lineages were found to have around 300 genes with significant evidence of positive selection. Many of these genes were functionally related to embryonic growth, immune system, and neuronal development. Although these genes likely represent parallel adaptations associated with brood parasitism, few genes were found to be under positive selection in both lineages. Therefore, in contrast to recent studies of gene expression that have identified relatively few genes associated with the convergent evolution of morphological traits, our results suggest that at the level of coding genes, independent changes are largely responsible for transitions to brood parasitic behavior.

104.5 LOVE, AC*; SMITH, AC; WILDER, SM; DURANT, SE; Oklahoma State University; *ashley.c.love@okstate.edu*

In sickness and in health: How do direct and indirect cues of infection influence pair bond maintenance?

Immune activation following infection can divert energy away from processes like reproduction. While immune activation is known to influence mate choice and reproductive investment in several taxa, relatively little is known about how infection influences courtship and pair bond maintenance behaviors in species that form pair bonds. Some pair bond behaviors may be costly to maintain during infection, and infection could also promote avoidance behaviors within an established pair. Thus, infection-induced changes in pair maintenance are a likely, but largely unexplored, route through which infection could shape reproductive decisions. Using zebra finches (*Taeniopygia guttata*), we examined how an immune challenge with lipopolysaccharide (LPS) influences pair bond maintenance in established pairs. We observed a decrease in activity in LPS-challenged birds relative to controls, consistent with LPS-induced sickness behavior. Immune activation decreased the number of times birds performed some courtship behaviors (e.g., beak-wiping), but increased the frequency of clumping between individuals within a pair. While clumping is considered a pair maintenance behavior, it likely serves an additional purpose during immune activation by reducing the thermoregulatory costs associated with maintaining a fever. Interestingly, LPS-challenged pairs decreased the amount of time spent near unmanipulated neighbors but only when sickness behaviors were more pronounced. We have demonstrated that immune activation alters the frequency of some pair maintenance behaviors and are currently examining whether an indirect cue of infection influences pair maintenance behavior in focal birds housed next to either LPS-challenged or control pairs.

P3.24 LOVE, CN*; WEBSTER, SC; BEASLEY, JC; HINTON, TG; BYRNE, ME; SHAMOVICH, D; LANCE, SL; Univ. of Georgia, Fukushima Univ., Vitebsk Region, Belarus; *love@srel.uga.edu*

Chernobyl's Legacy: Effects of Chronic Radiation Exposure on Carnivores from the Chernobyl Exclusion Zone

Nuclear energy production is increasing globally, yet long term ecological implications of radiation exposure from industrial practices or accidents are unclear. Acute radiation exposure causes morbidity and mortality and can affect immune responses. However, robust data are lacking regarding chronic radiation exposure. The Chernobyl Exclusion Zone (CEZ, evacuated since 1986) harbors a heterogeneous radioactive landscape (40 - >7,500 KBq/m^2) and offers an ideal system to investigate the effects of chronic radiation exposure. Carnivores are at higher risk for accumulation of contaminants due to their high trophic level and long life span and provide a good model system. We studied two carnivore species, the gray wolf (*Canis lupus*) and raccoon dog (*Nyctereutes procyonoides*), to allow for comparisons of exposure on species with differing spatial requirements and life history traits. During 2014-2016 we collected data on carnivores within the CEZ to examine the effects of radiation exposure, demography, and environmental attributes on parasite and disease prevalence. Radiation levels did not influence carnivore distribution, however, our preliminary data indicate a positive correlation between radiation exposure and parasite loads of *Coccidia* and *Alaria* species, which may indicate complex sub-lethal effects experienced by chronically exposed individuals. We are continuing this work to address parasite and disease prevalence as a function of radiocesium body burden counts, population density, and habitat characteristics to provide insight into population level implications of chronic radiation contamination exposure.

26.6 LOWDER, KB*; TAYLOR, JRA; University of California, San Diego; *kblowder@ucsd.edu*

Building specialized armor: investigation of the complex exoskeleton of the California spiny lobster

The California spiny lobster (*Panulirus interruptus*) is equipped with a diversity of predator defenses, such as a spine-laden carapace, rostral horns above the eyes, and whip-like antennae. Even though each of these defensive structures is part of the cuticular exoskeleton, they likely experience different loading regimes during predator interactions. Thus, parts of the exoskeleton that would benefit from specialization may have distinct material properties, which result from differences in their structure and composition. Here, we studied the structure, composition, and mechanical properties of three regions of the exoskeleton (carapace spine, horn tip, and antennae base) using SEM, energy-dispersive x-ray spectroscopy, and nanoindentation. We found that the horn tip consisted of an outer non-lamellar region and an inner lamellar core, whereas the antennae base and carapace spine both had typical layered cuticle. The antennae base had a thicker endocuticle than exocuticle, but the carapace spine had a thicker exocuticle, which was twice as thick as the exocuticle of the antennae base. The exocuticle of the antennae base and carapace spine both averaged approximately 30 wt% calcium, while the outermost region of the horns averaged just 2 wt% calcium. Additionally, the outer region of the horn was both significantly harder and stiffer than the epicuticle of the antennae base and the carapace spine, which likely resulted from its higher chlorine content (8 wt% more), an element linked to increased hardness in other arthropod exoskeletons. These results provide insight into how spiny lobsters, and crustaceans in general, modify the cuticle for specific roles, including protecting the animal from a variety of predator approaches.

102.2 LOZIER, JD*; PIMSLER, ML; JACKSON, JM; University of Alabama; *jlozier@ua.edu*

Population Genomics of Color Pattern Variation in a Widespread North American Bumble Bee

Variation in bumble bee color patterns is well-documented within and between species. Identifying genetic mechanisms underlying such variation may be useful in revealing evolutionary forces shaping rapid phenotypic diversification. The bumble bee *Bombus bifarius* is widespread across western North America, where populations exhibit regional variation in abdominal color forms, ranging from red-banded to black-banded phenotypes and including geographic and phenotypic intermediates. We sequence populations from a spatial and color pattern transect across the *B. bifarius* range using RNA sequencing and RAD-tag sequencing. We use this large high-throughput sequencing data set to first resolve the phylogeography and species-level divergence among geographic color forms. We then apply genome scans to identify genome regions associated with color pattern differentiation. Results have implications for the taxonomy of *B. bifarius* and the role of phylogeography for color pattern divergence. Genome scan results also reveal a candidate pigmentation gene that suggests the power of natural selection to make use of existing genetic mechanisms in novel evolutionary contexts to promote phenotypic differentiation.

2.1 LUCAS, KN*; TYTELL, ED; LAUDER, GV; Harvard University, Tufts University; *klucas@fas.harvard.edu*

Pressure-Based Measurement of Instantaneous Swimming Forces Produced by Bluegill Sunfish (Lepomis macrochirus)

Pressure is a fundamental modality through which aquatic organisms like fish interact with their surrounding environment. In particular, pressure fields are the source of the forces that allow a fish to move. To swim, a fish passes a sinusoidal wave of bending down its body, or moves its fins, creating localized regions of high and low pressure in the water adjacent to the body. By shaping the development and transport of these pressure gradients with their kinematics, fish produce the forces needed for swimming, turning, and station-holding. Despite the close coupling of pressure and forces, few studies have experimentally measured pressure fields, owing to the difficulty in obtaining these measurements, especially on fine spatial and temporal scales around the entire fish body. This has greatly limited our ability to examine real-time locomotor forces. Here, we use flow velocity vector fields, measured using digital particle image velocimetry, to calculate pressure fields in the water surrounding freely moving bluegill sunfish (*Lepomis macrochirus*), swimming steadily in a flow tunnel. From these, we derive instantaneous forces acting along the fish's body. We then examine the patterns of pressure and force distribution, and how they change as the bluegill shifts from pectoral fin propulsion at low speeds to body-caudal fin propulsion at high speeds. Future analyses will seek to understand how these fluid-body interactions lead to the flow structures shed into the wake, and how forces are modified during maneuvering.

126.1 LUGER, AM*; SCHOTTE, M; BAUM, D; HUBER, D; DEAN, MN; Max Planck Institute, Ghent Univ., Zuse Institute Berlin, Tampa Univ., Max Planck Institute; *allison.luger@ugent.be*

On the jaws of lamniform sharks: explaining function through morphology

Lamniform sharks vary widely in morphology and feeding niche, however, the functional morphology of their jaws is difficult to study due to their large size, rarity, and pelagic habit. To determine whether, and how, skeletal structure and performance vary with ecology, we created a custom analysis module for CT data to quantify aspects of structure of the jaw skeleton from all 15 members of Lamniformes. The module provides a customizable and slice-wise analysis of jaw structure, outputting shape-based descriptors relating to skeletal function, e.g. second moment of area, mineralized cross-sectional area, cortical wall thickness, and the anatomical orientation of each cross-section's major axis. These parameters help describe the contribution of jaw shape to skeletal bending and torsion resistance, while also localizing regions of reinforcement (e.g. higher wall thickness) and the likely predominant orientation of loading (based on distribution of material). Our results suggest diet-specific structural organization in the jaws, but also broad consistencies across the closely related lamniforms. The mineralized tissue of the jaws is arranged in such a way as to resist flexion ~5-20 times better than if it were a solid rod of similar length. The anterior tooth-bearing ends of both upper and lower jaws are rounder in cross-section implying higher torsion resistance, whereas the posterior ends (near the jaw joint and adductor muscle insertions) are extremely narrow, suggesting high, but anisotropic, resistance to flexion and a more uniform loading direction. These data suggest that skeletal geometry in sharks may be organized in predictable ways, as in bone, to resist dominant loading regimes. Furthermore, our CT data provide new anatomical insights, such as previously undescribed gaps in the mineralization layer near the jaw joints.

P2.80 LUKENS, K*; WAGNER, T; RIGGS, ; PODRABSKY, E; Portland State University; *klukens@pdx.edu*

In Situ Hybridization as a Localization Technique for miRNA in Austrofundulus limnaeus Cell Culture

In Situ Hybridization as a Localization Technique for miRNA in *Austrofundulus limnaeus* Cell Culture Kathleen K. Lukens, Josiah T. Wagner, Claire Riggs, Jason E. Podrabsky Department of Biology Center for Life in Extreme Environments Portland State University Portland, Oregon Understanding the role of microRNA (miRNA) expression and regulation is invaluable in modeling the cellular mechanisms associated with anoxia tolerance in the annual killifish *Austrofundulus limnaeus*. Development of an *in situ* hybridization (ISH) technique capable of specific and high resolution localization of target miRNA in cultured *A. limnaeus* cells would provide information about the location of miRNA in different sub-cellular compartments during periods of anoxia. ISH in the *A. limnaeus* cell culture system is a new technique and our objective is to develop a reliable protocol that can label with high specificity and localize within the structures of individual cells. Using immunohistochemistry (IHC) to fluorescently co-label the nuclei and mitochondria in conjunction with ISH can provide a map of miRNA transport and expression within the cell. Here, we use *β-actin* as positive control for RNA expression in order to optimize the ISH technique for *A. limnaeus* cell culture. Our protocol is suitable for both aerobic and anoxic cells, and accommodates IHC co-labeling of mitochondria and nuclei. Additionally, we demonstrate success in labeling for two expressed miRNAs in the same cell culture. Our results suggest differences in expression of target miRNA between anoxic and aerobic cells, thus indicating that microRNA expression and transport may play roles in the regulation of anoxia-induced quiescence in *A. limnaeus* embryos. Further development will be needed to improve specificity and reduce background labeling using this technique.

S3.4 LUTTERSCHMIDT, D.I.; Portland State University, OR; *d.lutterschmidt@pdx.edu*

Neuroendocrine control of the seasonal switch from reproduction to foraging in garter snakes

Many vertebrates exhibit distinct life-history stages that are associated with specific physiological and behavioral functions, such as reproduction, migration, and foraging. In seasonal organisms, resource availability relegates these life-history stages to a specific time of year, and therefore seasonal transitions between life-history stages are often accompanied by dramatic changes in both physiology and appetitive and consummatory behavior. Red-sided garter snakes (*Thamnophis sirtalis*) are an exceptional model for understanding the mechanisms mediating life-history transitions. We previously found that glucocorticoid hormones play a central role in the seasonal transition from reproduction to migration and foraging. We now aim to understand the mechanisms by which changing glucocorticoids mediate these behavioral shifts. Here, we present data describing interactions between glucocorticoids and two neuropeptides that induce potent and rapid changes in reproductive and feeding behaviors: arginine vasotocin (AVT) and neuropeptide Y (NPY). Both AVT and NPY change seasonally in male snakes, and the seasonal changes are specifically associated with the transition from reproductive condition to foraging. Further, experimentally decreasing plasma glucocorticoids with a synthesis inhibitor prematurely induces feeding behavior and also increases NPY-immunoreactivity in specific brain regions. Finally, prior studies show that exogenous NPY significantly increases feeding behavior, and our preliminary data suggest that AVT both elevates plasma glucocorticoids and increases male courtship. Collectively, these studies begin to elucidate how glucocorticoids interact with neuromodulators to induce the motivational trade-offs associated with complex life-history transitions.

71.3 LUTZ, EK*; RIFFELL, JA; University of Washington; *lutze@uw.edu*

Olfactory Learning in Aedes aegypti Mosquito Larvae

Aedes aegypti mosquitoes transmit serious diseases including Zika and Dengue fever, and use their chemosensory system to find appropriate hosts. We have shown that adult *Aedes aegypti* can readily learn host odors, which may allow them to find appropriate blood-hosts, avoid defensive prey individuals, or even select oviposition sites. However, less is known about learning ability of the larvae. Larval learning could play an important role in predator avoidance, finding food, or avoiding stressful environments. Furthermore, the sensory bases of these behaviors remain unknown. Here we demonstrate a new Pavlovian conditioning protocol tailored for aquatic *Aedes aegypti* larvae. Using computer vision algorithms to track the larvae, we can quantitatively analyze many facets of larval activity. Our results demonstrate that *Aedes aegypti* larvae are indeed capable of aversive olfactory conditioning. This learned behavior persists for at least 24 hours and appears to be specific to the learned olfactory stimulus. Further, we tested this same protocol on mosquitoes deficient for the olfactory co-receptor Orco. This obligate co-receptor is required for function of olfactory and gustatory receptors in *Aedes aegypti*. We expect Orco deficient larvae to exhibit no learned olfactory avoidance behavior, because of their inability to sense olfactory stimuli presented throughout an experiment. The odor-specific learning ability of *Aedes aegypti* larvae suggests that learning may be crucial for mosquito development and proliferation in the wild. Further research will provide valuable information that may be useful in preventing the spread of mosquito hosts of virulent diseases.

S6.1 LYNCH, Kathleen S.; Hofstra University; *kathleen.lynch@hofstra.edu*

Understanding receiver biases in reproductive contexts

Biases in female mate choice have been categorized as either belonging to sensory or learning-based biases. Historically, only learning-based biases have been considered to exhibit plasticity. It is now widely demonstrated, however, that sensory biases display substantial plasticity across all sensory modalities and nearly every taxonomic group. In addition, cognitive processes other than learning also affect mate choice, including attention, memorability and categorization. Furthermore, social behaviors including mate choice are not simply a product of sensory or cognitive processing but also include motivational and emotional processes as well. Thus, there are a number of critical ways in which we can better define the biases and processes that underlie mate choice decision making. Moreover, plasticity in sensory systems can be regulated by neuromodulators involved in cognitive, motivational and emotional regulation and plasticity in cognitive components also occurs with these same neuromodulators. Therefore, each of these underlying components (i.e. cognitive, sensory, motivational and emotional) can be functionally linked via neuromodulator actions. Thus, understanding mate choice based on acoustic signals requires integration of all components underlying mate choice and the neuromodulators that regulate and link these components together. This presentation will explore common themes in the integrative biology of cognitive, motivational, and sensory biases of mate choice across taxa. The aim of this presentation and our symposium is to build a new foundation in which to understand these processes not as modular systems but as a set of interacting processes that function together in a mate choice decision context and to identify future research directions in this interdisciplinary area of integrative biology.

94.3 M, MAITRI*; SANT, H H; POOVAYYA, MITALI; SANE, S P; National Centre for Biological Sciences, Bangalore, India, National Centre for Biological Sciences, Bangalore, Manipal University,Manipal, India; *maitrim@ncbs.res.in*

Role of Cephalic Mechanosensors in Flight Initiation of Hawkmoths

For insects, mechanosensory feedback about airflow relative to the body is crucial for airspeed control during flight, as well as the rapid detection of predators that may be dangerously close. Such feedback also plays a key role in flight stabilization during rapid maneuvers or long, steady flight bouts. We investigated the neural mechanisms of airflow detection in the Oleander hawkmoth *Daphnis nerii*, with specific reference to their role in flight initiation. Our behavioral experiments demonstrated a robust flight initiation response to frontal air gusts, as also observed in other insects such as locusts. Using a combination of behavioral, neuroanatomical and morphometric techniques, we identified subsets of mechanosensitive bristles in the cephalic hair system located on the posterior head region in hawkmoths. When stimulated by an air puff in tethered hawkmoths, these sensors cause the rapid, sequential and systemic initiation of multiple flight-related reflexes including antennal positioning, head stabilization, wing initiation, leg extension and abdominal flexion. The primary arbors of the cephalic mechanosensory neurons span the distance from head to the mesothoracic ganglion, the region where the flight motor neurons reside. Based on these data,we propose that these reflexes are sequentially activated due to the stimulation of the cephalic bristles.

P1.226.5 MA, Y*; REN, HL; NING, JG; ZHANG, PF; Beijing Institute of Technology; *mayun_ibrahim@163.com*

A study on the chordwise defomation and its influence on the aerodynamic performance of a hovering honeybee coupled-wing

Insect wings, for example a coupled-wing of a worker honeybee including a forewing and a hindwing, present obvious flexibility during the flapping flight, especially along the wing chord. In our study, the honeybee wing deformation along the wing chord during flight could be observed through the high-speed photography, and at the same time, the angle variation between the fore- and hindwing in one flapping cycle can be captured to represent the chordwise flexibility of the coupled-wing. In order to investigate the influence of the chordwise flexibility on the aerodynamic performance of a hovering coupled-wing, a flexible two-link model was considered and it was moving within the two dimensional viscous air through software ANSYS FLUENT. Harmonic kinematics deduced from attack angle changes and angle changes between the fore- and hindwing, were used to prescribe the motions of the two links. Under this circumstance, the aerodynamic performance, such as lift coefficient, drag coefficient and vorticity distribution over the fluid field, of the flexible two-link, would be compared with that of a rigid link at the same Reynolds numbers. The present study points to the importance of taking into account the chordwise flexibility for comprehending the aerodynamic performance of insect flight.

P2.62 MAAN, A*; CASS, AN; TULENKO, FJ; DAVIS, MC; Kennesaw State University, Monash University; *amaan@students.kennesaw.edu*

Early establishment of molecularly distinct skeletal compartments in paddlefish fins

Gnathstome paired appendages consist of two distinct skeletal compartments: a proximal endoskeleton which develops via cartilaginous condensations, and a distal fin-fold containing dermal rays that form via direct membranous ossification. These different modes of development, and the loss of the appendage dermoskeleton during the fin-to-limb transition, fueled the hypothesis that these skeletons form as separate developmental modules with their own evolutionary histories. This hypothesis was further supported by evidence that dermal rays might be neural crest derived, unlike the lateral plate mesoderm (LPM) derived endoskeleton. However, recent work has demonstrated that both skeletons are derived from the same progenitor LPM population. To further investigate the emergence of distinct skeletogenic cell populations from a common developmental origin, we herein describe the earliest events of fin development in a basal actinopterygian, the American paddlefish *Polyodon spathula*. In paddlefish, molecularly distinct compartments are established by the earliest fin-bud stages, presaging the ultimate arrangement of fin radials and actinotrichia in mature larvae. In order to determine the histological context for these events, we compare plastic-embedded ultratome cross-sections through the pectoral fin with the labeling domains of the prechondrogenic marker *Sox9* and the fin-fold actinotrichia marker *And1*. These data reveal cryptic molecular boundaries for nascent endoskeletal and dermoskeletal compartments. Additionally, we describe septations within the fin bud mesenchyme, which correspond with the remarkably precocious expression of *And1* in the same region. We use these new observations to test the hypotheses of current models of appendage differentiation and skeletogenesis.

96.3 MABOLOC, EA*; CHAN, KYK; School of Science, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, Division of Life Science, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong; *eamaboloc@connect.ust.hk*

Direct and Diet-mediated Indirect Effects of Ocean Acidification Do Not Impact Larval Slipper Limpet Crepidula onyx

Much attention has been given to the effects of ocean acidification (OA), a reduction in sea surface pH caused by the increased uptake of atmospheric carbon dioxide. OA is known to directly impact larval development and physiological processes of many marine organisms. In addition, OA is shown to affect the nutritional quality and algal palatability. This indirect effect of OA via trophic interactions, however, has not been fully explored. In this study, veligers of the slipper limpet *Crepidula onyx* were exposed for 14 days to different pH levels representing the ambient (as control) and projected near future pH values (pH 7.7 and pH 7.3), and were fed with the algae *Isochrysis galbana* cultured at these 3 respective pHs. Our results showed that larval mortality, growth rate, and respiration were not significantly affected by pH, food treatments, nor their interactions. Settlement rate did not differ significantly among pH treatments but showed an increasing trend towards decreasing pH. Shell morphology revealed minor but noticeable structural changes at low pH conditions. Larval size at day 14 and protoconch size also differed significantly among pH treatments. Our follow up experiment showed when exposed directly to reduced pH and/or fed with low-pH grown algae, larval clearance rates increased. This increase in food acquisition may serve as compensatory response to mitigate the impacts of OA and may explain the minimal effects observed in this study. Our work demonstrated that this non-native *C. onyx* population to be quite robust, if not, well adapted to future pH reductions and low algal nutritional value.

132.4 MACKAY, S.B*; BRERETON, C.; BERGMAN, D.A.; Grand Valley State University; *mackaysa@gvsu.edu*

Chronic Effects of Nonylphenol on Reproductive Behavior and Development of Crayfish

Nonylphenol (NP), an alkylphenol, is a commonly used surfactant in a variety of industries. Its chemical structure is composed of hydrophobic and hydrophilic regions, allowing for polar and nonpolar substances to be easily miscible. It is incredibly versatile, producing around 500,000 tons of alkylphenols annually. Due to its structure, NP shows an affinity for estrogen receptors, hence its classification as an endocrine disruptor; a potential danger to reproductive success. Various alkylphenols accumulate in aquatic environments and have been shown to have effects on both aquatic vertebrates and invertebrates. Moreover, several studies have shown the reduction in olfaction from NP exposure. As crayfish rely on olfaction in mating and courtship, impairment in this system would also lead to a decreased ability to locate a mate. Due to the endocrine disruptive effects of alkylphenols observed in testis development and diminished sperm production in a variety of species, crayfish are likely to exhibit similar results when chronically exposed to sublethal NP concentrations. We hypothesize that both juvenile and adult crayfish will exhibit a dose dependent decreased ability to locate a mate that will continue to decrease over extended exposure. After chronic exposure, we also expect the juvenile male crayfish exposed to increased sublethal NP levels will exhibit decreased testis development, while female juveniles with exhibit increased ovary size relative to controls. Observing both the behavioral and developmental effects of low but chronic NP exposure will provide insight to its potential effects on crayfish courtship, and subsequent ramifications on crayfish populations and ecosystems at current EPA level guidelines.

75.5 MACLEOD, KJ*; SHERIFF, MJ; OWEN, DAS; ENSMINGER, DC; LANGKILDE, T; PENNSYLVANIA STATE UNIVERSITY; *kjm67@psu.edu*

Stress kills: maternal stress reduces female survival and hatching success, but not hatchling survival, in eastern fence lizards

The environment experienced by mothers during gestation can have profound impacts on the phenotype and subsequent survival of their offspring via transgenerational maternal effects. Transgenerational effects of maternal exposure to environmental stressors are most often assumed to be negative. However, maternal stress effects could benefit offspring if it better adapts them to life in a stressful environment. In this study we experimentally explore the role of glucocorticoid hormones (produced in response to stressors) as a link between maternal stress and maternal and offspring life history. We subjected gravid eastern fence lizards (Sceloporus undulatus) to a chronic low-level stress treatment (topical application of a low-concentration dose of corticosterone) until laying. This treatment was designed to emulate the physiological effects of a single daily fire-ant attack, an ecologically relevant low-level environmental stressor. Hatchlings produced by these females were then raised in enclosures either with fire ants present or excluded to provide a test of whether maternal stress resulted in offspring better-adapted to stressful environments. Gravid females treated with a low dose of glucocorticoid hormone suffered a greater loss of body condition and experienced higher gestational mortality than control females. The eggs laid by physiologically stressed females were also less likely to hatch. Hatchling survival, however, was not influenced by maternal stress treatment, irrespective of their environment. This study provides evidence that maternal stress, mediated by glucocorticoids, can have important fitness costs imposed before offspring hatch.

91.6 MACMILLAN, HA*; KELLY, SP; BELOZEROV, VE; JONUSAITE, S; DONINI, A; York University, Toronto; *hmacmil2@gmail.com*

How to Minimize Accidental Leakage: Cold-Acclimated Drosophila Have Reduced Intestinal Paracellular Permeability

Chill susceptible insects, including the model species *Drosophila melanogaster* are incapacitated, injured, and killed by low temperature exposure before any freezing of their body fluids occurs, but adaptation and acclimation to low temperatures can facilitate substantial improvements in chilling tolerance. A growing body of recent studies on a range of insect models have suggested that injury and death at low temperatures are associated with a gradual loss of ion and water homeostasis across cellular membranes and epithelia. This loss of balance occurs most notably across the gut epithelia, where large ionic and osmotic gradients are constitutively maintained by high rates of transport. Dissipation of these gradients causes extracellular [K^+] levels to increase, which causes cell depolarization and ultimately cell death at low temperatures. It remains unclear whether this cold-induced disruption of homeostasis is related to a greater net transcellular leak of ions and water through channels and aquaporins, respectively, or whether the occluding junctions between adjacent epithelial cells are disrupted by chilling. In this presentation, we will demonstrate that some of the major structural proteins of the septate junctions of *Drosophila* are differentially expressed during cold acclimation, and that these modifications are associated with a reduction in the tendency for paracellular solute leak across the midgut epithelium before and during chronic cold stress. Cold-acclimated flies also maintain low hemolymph [K^+] during cold stress and consequently avoid chilling injury. Thus, specific changes to septate junction structure and stability likely aid in the maintenance of solute and water balance and may represent an important aspect of thermal acclimation with cascading metabolic and life history consequences.

145.3 MACPHEE, LR; Northern Arizona University; *larry.macphee@nau.edu*

Low Budget, Hands-On Labs and Activities Your Students Can Do Offline as Part of an Online Course

Computer simulations are great teaching tools, but they are often insufficient for teaching and learning concepts in the sciences. They tend to present over-simplified representations of the topic, and often limit the student's ability to deviate from the expected path. In contrast, hands-on labs and activities let students learn science the way it's actually conducted, by developing a hypothesis, setting up an experiment, collecting data, analyzing and interpreting the results. They can be messy and don't always turn out as expected, but that's the reality of how science progresses. But how do you offer students hands-on labs in an online course? The answer is to do the lab offline, using low-cost, easily obtainable materials, and have the students report back in the online environment. Yes, there are equipment limitations but, with creative lab design, most materials can be obtained from a pharmacy, grocery, or hardware store. I present a collection of low-tech, low-budget, high quality labs and activities that can be done safely by students working remotely, and offer a collection of strategies for verifying completion of the work and assessing student learning. These activities are free for you to use, share, and modify for your own purposes, and are suitable for an Introductory Biology course for majors or non-majors.

56.3 MACPHERSON, MAGGIE*; JAHN, ALEX; TAYLOR, CAZ; Tulane University, Universidade Estadual Paulista; *maggie.macpherson@gmail.com*

Convergent evolution on the morphology of migration within an entire songbird genus (Tyrannus)

Migration theory posits that inter-specific competition drives the evolution of migration. However, this view omits the role of genetic drift, natural selection, and intra-specific competition in shaping niches. We addressed this discrepancy by combining theories of niche divergence and the evolution of migration in birds to examine the evolution of niches in migratory, partially migratory and resident populations in the *Tyrannus* genus of birds. We found support for the hypothesis that migrants demonstrate evidence of resource polymorphism since they are more generalist foragers than residents along a gradient of increasing variation in morphology from fully resident to fully migratory populations. We found convergence of the morphologies of traits important for niche differentiation for migratory (generalist) versus resident (specialist) life history strategies. Our results demonstrate that differences in morphology between migrants and residents should not be taken conclusively as evidence of niche partitioning due to inter-specific competition. Instead, we suggest that intra-specific competition may promote resource polymorphism as one aspect of the suite of co-adaptations that are adaptive for migratory populations, compared to specialist resident populations. More research is needed contrasting inter- and intra-specific competition to improve our understanding of how these processes shape the evolution of divergent life-history strategies.

77.1 MACRANDER, J*; MORAN, Y; REITZEL, AM; University of North Carolina, Charlotte, Hebrew University of Jerusalem; *jmacrand@uncc.edu*

Predators, Prey, and Symbionts: Sea anemones (Actiniaria) as a dynamic model for coevolution in venom.

When considering venomous lineages, sea anemones (Actiniaria) are atypical in that they do not rely entirely on visual or olfactory cues, obtain nutrients from associated symbionts, and host ectosymbionts from lineages that are typical food sources. For these reasons, we will present summaries of our diverse studies highlighting how sea anemones are an opportune lineage to ask questions about venom in a coevolutionary context. The starlet sea anemone, *Nematostella vectensis*, is equipped with neurotoxins that exhibit a high number of gene copies throughout their distribution, with some toxins exhibiting regional diversity resembling coevolution potentially influenced by the presence of specific predators or prey. The emerging model sea anemone *Exaiptasia pallida* persist with and without endosymbionts (zooxanthellae), lending itself to become a focal species when studying symbiont presence/absence and their poorly studied toxin gene repertoire. The aggregating anemone, *Anthopleura elegantissima*, is a dominant intertidal species found along the Pacific coast of North America that naturally occurs in 3 distinct symbiotic states, with symbiont presence (*Elliptochloris marina* or *Symbiodinium muscatinei*) having a significant impact on venom gene expression. Finally, the long tentacle anemone, *Macrodactyla doreensis*, hosts both zooxanthellae and clownfish, which provide nutrients (and sometimes protection), likely a feedback mechanism impacting the overall toxin repertoire when in association. Across Actiniaraia these species engage in dynamic interactions with a variety of predators, prey, and symbionts; much of which we are only beginning to understand, making the lineage as a whole an ideal system to test hypotheses regarding venom evolution and function.

P2.209 MACRANDER, J*; DIMOND, J; BINGHAM, B; REITZEL, AM; University of North Carolina, Charlotte, Western Washington University; *jmacrand@uncc.edu*

Dueling Symbioses: An 'Omic Perspective into the Sea Anemone Anthopleura elegantissima and Their Zooxanthellate and Zoochorellate Symbionts.

While most symbiotic cnidarians associate exclusively with *Symbiodinium* spp., the sea anemone *A. elegantissima* naturally occurs in 3 distinct symbiotic states: zooxanthellate (hosting *Symbiodinium muscatinei*), zoochlorellate (hosting *Elliptochloris marina*), and asymbiotic (lacking symbionts altogether). Where their overlapping distributions converge (*E. marina* in the north and *S. muscatinei* in the south) symbiont specific abundances appear to coincide with preferred habitat type (i.e. cooler temperatures and decreased irradiance for *E. marina* vs. prolonged high-temperature and irradiance for *S. muscatinei*) and may play a key role in this species resilience to climate change. We use a combined transcriptomic and metabolomic approach to evaluate the genomic and metabolic signatures and potential contributions of each symbiont type. Overall gene expression profiles grouped according to symbiont association, with a large proportion of the upregulated genes being more highly expressed in *S. muscatinei* associated anemones. Our gene ontology (GO) analyses linked dozens of transcripts to some of the more inclusive GO terms, while others were associated with gene products that may play a role in mediating stable symbioses. Our principal component analysis of the metabolic data revealed that all anemones in each symbiont condition have more similar metabolite profiles to each other than to anemones in another symbiont association, with 154 of the 355 metabolites screened exhibiting significant differences among symbiont groups. This combined approach has allowed us to identify gene products and metabolites associated with maintaining stable symbioses in this resilient intertidal invertebrate.

121.3 MADELAIRE, C.B.*; CASSETTARI, B.O.; GOMES, F.R.; University of São Paulo; *cmadelaire@yahoo.com.br*

Effects of testosterone and corticosterone treatment on immunocompetence of anurans from the Brazilian semi-arid area

During the reproductive season, anuran males display high plasma levels of androgens (A) and corticosterone (C), associated with testicular development and vocal behavior. Steroid hormones are immunomodulators, and elevated steroid plasma levels steroid plasma levels during reproduction might affect immunocompetence. Anuran males from the Brazilian semi-arid, the Caatinga, show higher A and C plasma levels and immunocompetence, especially when calling. These data suggest that higher steroid plasma levels, associated with expression and maintenance of calling activity, show immune-enhancing effects. However, the direct effects of A and C on immunocompetence remain to be tested in these species. We collected 39 males of *R. jimi*, during the reproductive season and sampled blood through cardiac puncture to measure basal hormone plasma levels and plasma bacterial killing ability (BKA). Afterwards, animals were placed individually in plastic boxes and randomly separated in 5 treatment groups: Placebo [5 uL of vehicle (sesame oil)] (P), testosterone (T) low dosage (12ug of T propionate) (Tlow), T high dosage (20 ug of T propionate) (Thig), C low dosage (7 ug of C) (Clow), and C high dosage (14 ug of C) (Chig). The treatment was conducted 24h after animals were collected from the field. We collected a blood sample 1 and 12h after the treatment to obtain plasma hormone levels and BKA. After hormonal treatment, we also subjected the animals to a phytohemaglutinin (PHA) challenge. As stablished in previous studies, their paws were measured 0, 12 and 24h after the PHA injection. Both treatments (low and high) successfully increased the plasma levels of their respective steroids, 1 hour after treatment (Tlow, Thig, Clow, Chig). The effects of hormone treatment on the immunological parameters are currently in analysis, and will be discussed in the presentation.

P2.125 MADY, R*; SMITH, D; OUFIERO, C; Towson Univ. ; *rachael.mady@gmail.com*

Are the athletic ones the handsome ones? Part I: Linking female preference to aerobic locomotor performance in Xiphophorus montezumae

In many taxa, female mate choice has driven the evolution of elaborate male displays and ornamentation. There is evidence that females use these courtship displays, ornamentation, or both to assess a male's quality. In aquatic animals, females may assess and select for the best, or most efficient, swimmers via courtship displays. Swimming efficiency indicates how much energy an individual uses to swim; more efficient swimmers use less energy at a given speed, allowing them to potentially swim longer. More efficient male swimmers may be able to last longer in courtship, demonstrating his quality to the female and out-competing other males in male-male competition. On the other hand, swimming efficiency may be honestly indicated by ornamentation and not courtship displays. Few studies have yet to conclusively link female preference to swimming efficiency. The objective of this study was to determine if females prefer males based on their swimming ability, morphology, or a combination of traits using *Xiphophorus montezumae*. *X. montezumae* males are distinguished from females by their "sword," or elongated caudal fin. This species has been repeatedly used to assess female preference and male locomotor performance, but none have linked the two. We quantified male swimming efficiency by steady swimming energetics tests in a respirometer, and female preference by dichotomous preference tests. Male morphology was quantified by several metrics, including sword length. The results will be discussed in the context of previous work in this species and others on female preference and locomotor performance in relation to sexual selection.

47.8 MAH, JL*; LEYS, SP; University of Alberta;
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Using RNAseq to Probe the Pre-Neural Character of the Sponge Sensory System

Sponges, an animal without nerves, have an intriguing number of neural developmental and structural genes. Moreover, some demosponges can sense changes in flow and respond with a choreographed inflation-contraction behavior that flushes obstructions from the canals. Sensory abilities and initiation of this behavior can be traced to primary cilia in the osculum, the excurrent vent of the sponge. Thus while the genetic mechanisms remain unknown the osculum may function as a sensory and coordinating hub. In the calcareous sponge *Sycon ciliatum* the neurodevelopmental genes SoxB and Musashi are upregulated at the top of the sponge, which is both the growing region and location of the osculum. However, a sensory system in this sponge has not yet been documented. To investigate whether such genes may be involved in the development of the osculum, we performed an RNAseq experiment in the demosponge *Spongilla lacustris* using sponges that were flash frozen during the stages preceding and following osculum development. In addition, we performed a second RNAseq experiment comparing gene expression in the osculum vs. body tissue of *Aphrocallistes vastus*, a deep sea glass sponge that possesses oscular cilia and exhibits a behavioral response to changes in ambient flow. *Aphrocallistes* also has electrical signaling and we asked whether genes involved in neural signaling in other animals are more highly expressed in that sponge's osculum. In probing the genetic mechanisms of the osculum we aim to investigate the shared biology of sensory structures across animals while characterizing the foundations of a unique, sponge-specific sensory system.

P1.251 MAIA, A*; PARRISH, A; HAMMOCK, K; FAVATA, CA; Eastern Illinois University; *amresendedamaia@eiu.edu*

Median fin function, morphology and development in basal bony fishes

Fin evolution has allowed for the diversification of fish morphology and subsequent exploration of new habitats. Basal bony fish have elongated body shapes where the pectoral and pelvic fins have a basal position and contribute little to thrust. Less is known about the role and evolution of median fins, especially anal and dorsal fins. We examined three species of sturgeon, gar and bowfin across ontogeny to assess diversity in median fin morphology with a geometric morphometrics approach. Larval series were used to describe timing of fin development, and to document caspase-3 function in median fin patterning. Lastly, in the lab, we swam gar and sturgeon to determine the role of median fins during steady and unsteady swimming. Geometric morphometrics was successful in separating basal fish species based on median fin morphology, although differences between species became more pronounced over ontogeny. In basal fishes, the dorsal fin is the first to undergo development, followed closely by the anal fin. Caspase-3 activity was mapped to the fin fold in the regions flanking the median fins at the beginning of fin formation. Our kinematic data show that gar and sturgeon use the dorsal and anal fins in phase to augment thrust from the caudal fin during steady swimming. During acceleration, dorsal and anal fins are also actively recruited. Despite their markedly different fin morphologies, gar and sturgeon display similar median fin kinematics, which contrast the previously described ribbon-fin kinematics of bowfin. Our study shows that basal fish rely heavily on median fins for locomotion, and diversification of fin shape might have important evolutionary implications to distribution and ecology.

P3.181 MALOIY , GMO; RUGANGAZI , BM; ROWE , MF*; Univ of Nairobi, Univ of the West Indies; *michael.rowe@uwimona.edu.jm*

Preliminary Assessment of Gait Specific Heat Storage in Large Desert-Adapted Ungulates a Dromedary Camel and Domestic Donkey During Submaximal Treadmill Exercise

Gait specific variations in the rate of heat storage may result in differential ability to conserve water in the dromedary camel ("*"Camelus dromedaries"*") and domestic donkey ("*"Equus asinus"*"). Specifically, we sought to determine if the portion of cost of transport,COT (J.kg-1m-1) stored in core body tissues remained constant during 30-minutes of treadmill exercise in a walking gait (tread speed of 1.1m.s-1) and moderate speed (2.2m.s-1) gait, pacing and trotting in the camel and donkey, respectively. We continuously measured mass-specific oxygen consumption, and rectal temperature as an indicator of core body temperature, "*"T"*"b (°C),recorded these data at one minute intervals and averaged every five-minutes. The exercise trials were divided into three-stages: pre-exercise (20-min), exercise (30-min) and post-exercise (20-min). In addition we estimated the total volume of water conserved. The camel and donkey had pre-exercise mean core body temperatures of 36.0 ± 0.05 °C and 37.8 ± 0.05 °C, respectively. Regardless of gait, heat storage accounted for approximately 23% of COT in the donkey. However, heat storage accounted for approximately, 30% and 80% of COT in the walking and pacing gaits, respectively. As a result of enhanced heat storage in the pacing camel, mass-specific water conservation in the camel was approximately 3.2-fold greater than in the trotting donkey. During 30-minutes of moderate speed gaits, enhanced heat storage allowed the camel to conserved approximately 0.7 L of water, compared with approximately 0.2 L of water in the donkey.

P3.197 MALPICA, AM*; LANGERHANS, RB; MOORE, BC; Sewanee: The University of the South, North Carolina State Univeristy; *malpiam0@sewanee.edu*

Comparing Two Techniques of Analyzing Sexual Dimorphic Gambusia affinis Skeletal Structure: Clearing and Staining to X-Ray

Male mosquitofish (*Gambusia affinis*) have sexual dimorphic skeletal characteristics that are establish during development: namely enlarged hemal spines and an anal fin elongated into a gonopodium. Enlarged hemal spines serve as anchoring points for muscles that direct the elongated anal fin, gonopodium, during its use in copulatory sperm transfer. To investigate these structures, the classic technique has been to enzymatically clear the fish tissues, stain ossified tissues with Alizarin red, and observe under a dissecting microscope. While reliable, this technique is time consuming. Here we compare clearing and staining of male mosquitofish with imaging results obtained from high-resolution x-ray. Specifically, we examine the resolution of sexually dimorphic male skeletal features and discuss perceived advantages to high resolution x-raying, including more rapid sample processing.

P3.76 MANCUSO, ML*; ADAMS, K; STOUT, JS; Fairleigh Dickinson University Metro Campus; *molly96@student.fdu.edu*
Dopamine Inhibition of Activity Levels in the Cherry Shrimp (Neocaridina davidi).
Dopamine is known to have inhibitory functions and yet, dopaminergic drugs, such as caffeine and cocaine are stimulants. Thus, many experiments show increased activity levels in organisms given dopaminergic substances. This seeming paradox is a result of the brain blood barrier of vertebrates preventing the administration of dopamine directly. Dopamine can be given directly to crustaceans, such as cherry shrimp, because they lack the tight brain blood barrier seen in vertebrates. Shrimp given food filtrate or glutamic acid show increased activity levels over controls, and decreased activity levels when exposed to dopamine (3.27 µmol) ($p<0.001$). This implies that the increased activity level seen in vertebrate models is due to other factors released by stimulants, such as adrenalin, rather than dopamine. Inhibition of dopamine in shrimp through the D2 receptor blocker Haloperidol (3.27µmol) restores activity ($p<0.001$). A comparison of activity levels is also being determined using the D1 dopamine receptor antagonist SCH3390. This will determine if dopamine caused activity inhibition is generalized between receptor types or specific to the D2 site.

90.6 MANESS, TJ*; ANDERSON, DJ; Louisiana Tech University, Wake Forest University; *tmaness@latech.edu*
Developmental tradeoffs during poor rearing conditions in a seabird
Some species reach a smaller size under poor food conditions during early development, whereas in other species final size is not affected. This discrepancy may reflect variation in the importance of structural size in obtaining resources later in life. An offspring with limited energetic resources may face developmental tradeoffs, and rather than reducing overall growth uniformly, resources could be directed toward growth of vital systems or structures or growth could be slowed or reduced in some areas and not others. Seabirds may be expected to prioritize growth of flight feathers since newly independent seabirds must learn to locate temporally and spatially variable food sources over vast areas, often using difficult and complex foraging methods. We examined growth of 2631 offspring that reached the fledgling stage from seven annual cohorts of a seabird, the Nazca booby (*Sula granti*). We found that nestling growth was compromised under poor rearing conditions: growth rate was slower, overall body mass fell, and growth of some, but not all, structures was reduced. In particular, culmen length was reduced, while wing length was not. This result is supported by the fact that wing length, but not culmen length, is positively associated with juvenile survival in this species.

117.5 MANGALAM, M.*; PACHECO, M.M.; FRAGASZY, D.M.; University of Georgia; *madhur.mangalam@uga.edu*
How Wild Bearded Capuchin Monkeys Crack Nuts
Tool use is not unique to humans; a few wild populations of nonhuman animal species use tools as well. While channeling the organization of movements as per task demands is a defining feature of tool use in humans, we lack information about this aspect of tool use in nonhuman animals as quantifying movements under free-ranging conditions is usually difficult. In the present study, we analyzed how wild bearded capuchin monkeys, *Sapajus libidinosus* organize their movements when using anvil-and-hammer tools to hit a piaçava palm nut. They mostly use the lower back, hip, and knee, with only limited movement of the elbow, shoulder, and wrist. Their tendency to rely on the movement of the hind limbs and trunk increases as hammer mass increases in relation to the body. They organize their movements to maintain the velocity of the hammer at the moment of impact (a first order parameter) rather than maintaining the kinetic energy of the hammer (a second order parameter) as humans do. In this way, although relatively inefficient, wild bearded capuchin monkeys have developed a skillful method to meet the demands of the nut-cracking task.

P1.187 MANGALAM, M.*; FRAGASZY, D.M.; ROLES, L.K.R.; University of Georgia; *madhur.mangalam@uga.edu*
Wild Bearded Capuchin Monkeys Outperform Humans in Cracking Nuts
Tool-assisted percussion was, and still remains, a key way in which hominins alter their environment. Tool-assisted percussion is not uniquely hominin, as a few wild populations of bearded capuchin monkeys, long-tailed macaques, and chimpanzees habitually use percussive tools. Knowing species-specific differences in percussive skills allows us to address fundamental questions about the evolution of tool-assisted percussion in hominins. In the present study, we quantified percussive skill in wild bearded capuchin monkeys, *Sapajus libidinosus*, novice humans (scientists), and expert humans (local residents) at Fazenda Boa Vista, Piauí, Brazil, as they used anvil-and-hammer tools to crack open tucum palm, *Astrocaryum* spp. nuts. Astonishingly, the monkeys outperformed the novice humans, and the expert humans outperformed the monkeys, in terms of the number of strikes to crack open a single intact nut. The monkeys hit a nut repeatedly with a moderate force (i.e., by not exceeding a threshold) and modulated the force of each hit on the basis of the condition of the nut (i.e., the development of a fracture/crack) following the preceding hit. The novice humans, although they hit with a force comparable to that which the monkeys used, had to hit the nut a large number of times to extract the kernel. The expert humans hit with a force greater than that which the monkeys used and extracted the kernel of the nut in just a few hits. Together these results suggest that nut-cracking skill in both bearded capuchin monkeys and humans are embodied, with actions grounded in the musculoskeletal system and perception-action routines, and not anticipatory, with actions divorced from the task and environment. Thus, hypotheses linking skillful percussion uniquely to hominins demand reassessment.

P1.54 MANNA, TJ*; COOPER, C; BAYLIS, S; SHAWKEY, MD; WATERHOUSE, GIN; GRIM, T; HAUBER, ME; CUNY Hunter College, North Carolina Museum of Natural Sciences, Monash University, University of Akron, University of Auckland, Palacký University; *tommyjmanna@gmail.com*

Does the House Sparrow Passer domesticus Represent a Global Model Species for Egg Rejection Behavior?

Conspecific brood parasitism (CP) is a facultative breeding tactic whereby females lay their eggs in the nests of conspecifics. In some species, potential host individuals have evolved the ability to identify and reject foreign eggs from their nest. Previous studies suggest that the ubiquitous House Sparrow *Passer domesticus* in Spain and South Africa employs both CP and parasitic egg rejection, while a population in China does not. Given the species' invasive range expansions, the House Sparrow represents a potentially excellent global model system for egg rejection across variable ecological conditions. The present study examines House Sparrow responses to experimental parasitism at three geographically distinct locations (in Israel, North America, and New Zealand) to provide a robust test of how general the findings of the previous studies are. In all three geographic regions egg rejection rates were negligible and not statistically different from background rates of disappearance of control eggs, suggesting that the House Sparrow is not a suitable model species for egg rejection experiments on a global scale.

86.5 MANTILLA, DC*; HSIEH, ST; Florida International University, Temple University, Philadelphia, PA; *dmant010@fiu.edu*

Evaluating the Role of Claws and Toepads During Running in Anole Lizards

Caribbean Anolis lizards evolved subdigital toepads—similar to those found among geckos—as a key innovation that allowed them to invade a diversity of niches. Like other lizards, anoles have claws, which presumably function in concert with the toepads to aid adhesion when climbing. However, the interactive function of claws with toepads is not well understood in anoles. Having claws and toepads could be beneficial when climbing, by providing a greater diversity of adhesive mechanisms on unpredictable terrain. Conversely, claws may hinder adhesive abilities when moving on smooth surfaces by interfering with the toepad's contact with the surface. We examined the effects of incline and surface variations on running performance of three anole ecomorphs. Lizards were tested on a level and incline surface tilted at 45°, while covered with nylon mesh facilitating claw use, and while covered with Plexiglas isolating toepad use. We hypothesized that all anole lizards would perform similarly on level surfaces, but the arboreal ecomorphs would be more robust to the treatments on incline surfaces. On the level, no significant differences were found in running speed among ecomorphs regardless of whether they were able to use their claws and/or toepads. Surprisingly, when running on the 45° incline, the trunk-ground anoles (*Anolis sagrei* and *A. cristatellus*) seemed to be less affected by running on Plexiglas than the "trunk-crown" ecomorph (*A. carolinensis*) and trunk anoles (*A. distichus*). These more arboreal species presented significantly reduced running speeds and slipped while running on the plastic-covered incline. These results suggest that unlike among many geckos, anole claws are critically important for amplifying the adhesive capabilities of the toepad-claw system.

P3.257 MARIAN, AD*; WASS, ED; GERALD, GW; Nebraska Wesleyan University; *amarian@nebrwesleyan.edu*

Scaling of Resting Metabolic Rates in Cornsnakes (Pantherophis guttatus) with Comparisons to Other Snakes Varying in Activity Levels

Resting metabolic rate usually scales with body mass to between the 0.67 and 1.0 power when assessing the relationship with a power function ($R = aM^b$). For many animals, this relationship tends to not be significantly different from ¾. It has been suggested that when *b* is closer to 0.67, maintenance costs are higher and *b* is more limited by the movement of resources across body surfaces. When *b* is closer to 1.0, maintenance costs are lower and energetic demands of tissues drive the scaling relationship. Moreover, *b* has been shown to be negatively correlated with the metabolic coefficient or level (*L*) for resting metabolic rates in a variety of animals. However, data on limbless animals is somewhat scarce. Here, we examined the allometric scaling of resting metabolic rate in cornsnakes (*Pantherophis guttatus*) (N = 27) to compare the relationships with other species and assess the influence of activity level on both *b* and *L*. Combining our data with that collected on other snake species, we examined the hypothesis that *b* and *L* are inversely related in snakes, as has been shown in other animals. Conversely, we found that *b* and *L* were positively correlated in snakes and that snakes exhibiting more active lifestyles possess lower *b* and *L*. It is unclear why snakes differ from other animals. We hypothesize that snake body shape (mass relative to length) or the high-energy requirement needed to digest larger meals could be contributing factors to this puzzling relationship.

P3.153 MARKS, C*; NICKLES, N; WISE, T; MAVROIDIS, S; University of Mount Union; *markscp@mountunion.edu*

Incubation Temperature Alters Post-Hatching Temperature-Specific Metabolic Rates in the Northern Bobwhite Quail Colinus Virginianus

Developmental conditions can have lasting impacts on organismal phenotypes. Avian development in particular can be altered by relatively small temperature changes experienced during incubation. In order to examine the effects of incubation temperature on post-hatching metabolism, we reared northern bobwhite quail in one of two temperature treatments (35.5°C or 37.5°C). We then measured the metabolic rates of hatchlings in both temperature treatments. Quail hatchlings exhibited higher metabolic rates when tested in the temperature different from their incubation temperature, regardless of the post hatching temperature being higher or lower than the incubation temperature. This resulted in a significant interaction between incubation temperature and post-hatching temperature. Our results suggest that long term metabolic rates in northern bobwhites can potentially be determined by conditions during incubation. More generally, our findings reiterate the impact developmental conditions can have on long term phenotypic expression.

P1.158 MARKSTEIN, K*; STILLMAN, J; San Francisco State University; *markstkp@lemoyne.edu*

Optimum environmental temperature for the freshwater shrimp Neocaridina

Neocaridina, a genus of freshwater shrimp, has been suggested as a promising new model decapod crustacean for genetic manipulation due to their ease of culture, short generation time, thin and transparent cuticle, and lack of a pelagic larval stage. This project is aimed to develop techniques for *Neocaridina culture*, including identification of optimal temperature and methods for anesthetization. In order to determine the optimum temperature for *Neocaridina*, acute routine metabolic rate was studied at 22 to 32°C. Adult *Neocaridina denticulata* and *Neocaridina heteropoda* were used to determine standard metabolic rate. Within this range of temperatures, metabolic rate ranged between 4.962 and 29.183 µmol O2/min/g. Data from one test group suggested an optimal temperature of 30°C. Shrimp anesthesia was attempted to determine basal metabolic rate as well as to remove embryos from females. Several chemicals were tested on the shrimp. Clove oil was chosen because it has been a successful anesthetic for several species of fish. Shrimp were successfully anesthetized after about 20 minutes of immersion but all concentrations had high mortality rates, the lowest having a mortality rate of 83%. $MgCl_2$ has been an efficient anesthetic for cephalopods; shrimp were anesthetized after about 15 minutes but had a mortality rate of 100%. Tricaine methanesulfonate is often used to anesthetize many species of fish. In this solution the shrimp had a mortality rate of 100%. Kava kava root extract, containing kavalactones and alcohol, was suggested as an anesthetic by a hobbyist. In kava kava root extract solution, shrimp were anesthetized after about 40-60 minutes and had a mortality rate of 0%. Ethanol solutions at the same concentrations as the extract solutions were then tested but did not anesthetize the shrimp. Based on these results, kavalactones is suggested as the most successful anesthetic.

P1.238 MARQUES, I*; CLIFTON, GT; BIEWENER, AA; State University of Campinas, Sao Paulo, Brazil , Concord Field Station, Harvard U., Bedford, MA, CFS, Harvard U., Bedford, MA; *isabela.marques.bio@gmail.com*

Foot Shape Variation Within Foot-propelled Swimming Birds

Within the great diversity of birds, many lineages have colonized aquatic environments. Birds that swim using their feet face opposing constraints for locomotion. Underwater, birds benefit from large feet that can produce stronger fluid forces. Plus asymmetrically shaped feet could produce valuable lift forces. But on land, large, asymmetrical feet make walking unstable. From these differing demands we expect foot size and shape to vary with the degree of aquatic specialization. To test this hypothesis, we photographed and analyzed 50 feet of 6 bird species ranging in swimming ability: from surface swimmers—mallards (*Anas platyrhynchos*), Canada geese (*Branta canadensis*)—to specialized diving birds—double crested cormorant (*Phalacrocorax auritus*), Western grebe (*Aechmophorus occidentalis*), red-throated loon (*Gavia stellata*), common loon (*Gavia immer*). We measured foot size using normalized foot area and digit lengths. To measure shape, we compared medial to lateral areas, digit length ratios, digit splay angles, and Elliptic Fourier shape Descriptors (EFDs). Surprisingly, we find that specialized diving birds do not a have larger relative foot area except for grebes ($p<0.05$). All swimmers demonstrate some foot asymmetry. In specialized divers digit IV is longer than digit II, the inverse of surface swimmers. Discriminant analysis of the EFDs shows that the foot shapes of grebes and red-throated loons are distinct. Although cormorants have four webbed toes, their foot shape overlaps with the three-webbed-toed birds. Our findings reveal patterns in foot shape underlying swimming specialization, with implications for understanding evolution in aquatic animals and with potential applications for robotics or industrial design.

103.4 MARSHALL, KE*; ANDERSON, KM; BERNHARDT, JR; BROWN , NE; DYTNERSKI, JK; FLYNN, KL; GURNEY-SMITH, H; KONECNY, CA; HARLEY, CDG; University of Oklahoma, University of British Columbia, University of Hong Kong, Department of Fisheries and Oceans; *kemarshall@ou.edu*

Thermal sensitivity at constant temperatures does not predict responses under varying temperatures

Predicting the effects of climate change on organisms' physiology, fitness, and potential geographical distribution relies on a clear understanding of the effects of temperature on fitness measures. While organisms live in environments that regularly fluctuate in temperature, most studies on temperature sensitivity have focused on the effects of constant temperature conditions, which may have very different physiological effects. In this study we compared the responses of the bay mussel *Mytilus trossulus* from Tofino, British Columbia (outer coast) and Port Moody, British Columbia (inner coast) to either six weeks of constant temperature acclimation at 6, 12, or 18 °C or to temperatures that regularly fluctuated between 6 and 18 °C (with a mean of 12 °C). In a diverse suite of fitness measures (feeding and heart rate, growth rate, survival, and byssal thread production), we found that responses to variable temperatures were always significantly different than to constant temperature acclimation. In addition, each population showed unique responses to thermal acclimation, with mussels from Tofino being generally less sensitive to temperature than the mussels from Port Moody. These results suggest that projections of species responses to climate change based on experiments involving constant temperatures are likely to inadequately capture the complexity of responses under more natural, fluctuating conditions.

P2.273 MARSHALL, CA*; GHALAMBOR, CK; Colorado State University; *cam13@colostate.edu*

The effects of short- versus long-term salinity acclimation on resting metabolic rate and internal osmolality in Trinidadian swamp guppies

Salinity tolerance is a defining factor in shaping geographic range limits of many species. Nonetheless, the influence of salinity tolerance on patterns of dispersal and local adaptation are understudied for most species. Aquatic euryhaline species are capable of acclimating to a wide range of salinities; however, most species typically exhibit a preference. For example, previous work in euryhaline teleosts indicates that crossing a salinity gradient typically results in increased oxygen uptake and energetic costs for the organism. In Trinidad, swamp guppies, *Poecilia picta*, are found in adjacent fresh and brackish water habitats, but the degree to which these populations are locally adapted to various salinities is unknown. We investigated their physiological responses to changes in salinity on different temporal scales to determine whether the physiological response to variations in salinity is locally adaptive. We split wild-caught individuals from each population and laboratory acclimated them to fresh (0ppt) and brackish (30ppt) water over a 5-month period. Through gradual acclimation, we simulated slow movement along a salinity gradient. We then tested the effect of a rapid acclimation on different individuals through a fast-changing salinity titration to simulate conditions these fish might encounter during dispersal or flooding events. We also quantified the internal osmolality of these fish to determine their ability to maintain osmotic constancy. If the populations are locally adapted, we predict that elevations in metabolic rate will be higher when fish are exposed to their "away" salinity conditions in both treatments. We also predict that plasma osmolality will be closer to the solute concentrations found in the environment of those individuals with the lowest metabolic rate.

P3.145 MARTIN, KL*; HIEB, KA; ROBERTS, DA; Pepperdine University , California Department of Fish & Wildlife, NOAA, Cordell Banks National Marine Sanctuary; *karen.martin@pepperdine.edu*

Beach-Spawning California Grunion Show Effects of Climate Change on Reproduction

Surfing onto shore on moonlit nights, California Grunion *Leuresthes tenuis* completely emerge from water during spectacular spawning runs to deposit their eggs on sandy shores of southern California. This endemic species may be particularly vulnerable to effects of climate change on reproduction because of its beach-spawning habits. Not only must the adults cope with changing water temperatures, but the embryos require oviposition on sandy beaches and develop out of water. Remaining in the sand until triggered to hatch by rising tides, the embryos may be affected by rising air temperatures as well. Because of this unusual life history, *L. tenuis* may be a key indicator of the early effects of climate change, as it is already showing effects of ocean warming. The spawning runs reported recently may be less extensive in traditional habitat range of southern California than in the past. New spawning runs have been observed farther north, where this species never occurred previously. For *L. tenuis* in San Francisco Bay and more northern areas, adults grow to a smaller adult size, produce smaller and fewer eggs, reproduce less frequently, and live shorter lives than their southern counterparts. This makes them more vulnerable to short-term local disturbances and local extirpation. Thus a habitat shift more northward may lead to changes in reproduction and life history in this species that may not be as sustainable over the long term for populations as those in traditional habitats are.

89.4 MARTIN, LM*; ESBAUGH, AJ; The University of Texas at Austin; *leighann.martin@utexas.edu*

Osmoregulatory plasticity during hypersalinity acclimation in a euryhaline teleost

Prolonged drought and diversion of freshwater inflow into estuaries are making periods of hypersalinity more common in coastal systems. This is especially true in the Laguna Madre system along the Texas coast where salinities regularly exceed 70 ppt. As such, the ability to tolerate hypersalinity is critical to the success of species within these environments, such as the commercially important red drum (*Sciaenops ocellatus*). This study evaluated acclimation of red drum to hypersalinity (60 ppt) using a direct transfer protocol. Hypersalinity exposure resulted in significant impacts on plasma osmolality and muscle water within the first 24 h. These changes returned to control values coincident with a significant increase in intestinal water volume, which suggests increased osmoregulatory capacity as a result of acclimation. Acclimation to hypersalinity also resulted in significant upregulation of NKA and VHA enzyme activity for the posterior intestine and gills at 72 h post-transfer. Gene expression data supported these findings and additionally demonstrated a strong response for *nkcc1* and *nkcc2* in the gills and intestines, respectively. Overall, these data show that red drum are capable of tolerating acute bouts of hypersalinity exposure through osmoregulatory plasticity.

S8.3 MARTIN, L. B.*; SCHREY, A. W.; HANSON, H. E.; KILVITIS, H. J.; Armstrong State University, University of South Florida; *lbmartin@usf.edu*

The role of physiological integrators in avian range expansions

Range expansions are becoming more common as humans move organisms around the planet and alter the climate, forcing species to adjust to new conditions or move to new areas. Some organisms appear better able to endure new conditions than others. Indeed, some introduced species often become pests in new areas, spreading rapidly across habitats they never occupied previously. In many plants and invertebrates, phenotypic plasticity is a particularly important mechanism influencing range expansion; in vertebrates though, there is less evidence for plasticity as a driver of success in new areas. Here, we discuss the potential role of phenotypic plasticity in range expansions of house sparrows, one of the world's most common birds. In particular, we discuss how variation in the regulatory architecture of glucocorticoids, steroid hormones that affect various organismal functions, and a few other key genes (i.e., Toll-like receptors) might have been important to multiple range expansions of house sparrows (i.e., Kenya, Senegal, and North America). We propose that 'epigenetic potential', the propensity for some individuals to adjust gene expression via DNA methylation and related mechanisms, partly facilitated the colonization success in this species. Specifically, we expect that house sparrows are exceptionally capable of altering the roles of key nodes in physiological regulatory networks, which gives them exceptional abilities to adjust to prevailing conditions, even when such conditions are evolutionarily novel.

102.4 MARTINDALE, M.Q*; STEPHENSON, B. Q; DUBUC, T.Q; Univ. Florida; *mqmartin@whitney.ufl.edu*

The Hox code was present in the cnidarian-bilaterian ancestor and patterns the oral-aboral axis prior to gastrulation.

The Hox family of transcription factors have been well studied in many bilaterian clades and are generally thought to translate positional information along the primary body axis, the anterior-posterior axis, according to a "Hox code". The Hox code includes aspects of spatial and temporal colinearity and functional dominance of more posterior Hox genes known as "posterior prevalence". Here we use qPCR to show that Hox genes from a member of the sister group (Cnidaria) to the bilaterians, the starlet sea anemone, Nematostella vectensis, are activated earlier than previously reported and in a temporally colinear manner according to the presumed ancestral cnidarian Hox cluster. A bona fide anterior Hox gene (Ax6) is expressed at the animal (oral) pole and a bona fide posterior Hox gene (Ax1) in the vegetal (aboral) pole at blastula stage embryos. Using antisense morpholino knockdown and mRNA overexpression we show that, each gene not only patterns the differentiation of its own expression domain (e.g. anterior Hox expression is required for gastrulation/endomesoderm formation and oral development), but also impacts the development of the opposing pole, together patterning the entire oral-aboral axis. Furthermore, Ax6 and Ax1 interact with one another to control their respective oral and aboral expression domains. Interestingly we have noted that the posterior Hox gene negatively regulates oral development while the anterior Hox gene does not directly regulate aboral specification, thus showing signs of bilaterian "posterior prevalence". These data support an ancient role for Hox genes to pattern the primary body axis of the cnidarian-bilaterian ancestor prior to gastrulation, demonstrate a rudimentary Hox code, and provide additional evidence that the oral pole of cnidarians is homologous to the anterior pole of bilaterians.

P2.146 MARTINEZ, V*; TAUB, E; FREEMAN, A; Adelphi University, Garden City; *vanesamartinez@mail.adelphi.edu*
The Native Eurypanopeus depressus Mud Crab is More Inhibited by Malathion Exposure than the Invasive Hemigrapsus sanguineus Crab.

Malathion is an organophosphate insecticide that is commonly used in agricultural, public health, and residential settings, with over 16.7 million pounds being sprayed per year in the United States. This chemical can be broken down into non-toxic and toxic compounds, including malaoxon. Malathion and malaoxon inhibit acetylcholinesterase in many organisms, leading to involuntary movement or paralysis. Because malathion can drift during application, concentrations high enough to cause mortality in invertebrates have been discovered far outside of the target area. This study compares the effects of malathion on two invertebrates, the invasive crab *Hemigrapsus sanguineus* and the native panopeid mud crab *Eurypanopeus depressus*. Crabs were exposed to three ranges of malathion exposure; control (0ppb), middle (32-64ppb), and high (100-256ppb) concentrations. The impact of the insecticide was then evaluated using a standardized assay of righting behavior; placing affected crabs on their backs and measuring how long it took them to turn over. When the righting times of the *Hemigrapsus* and *Eurypanopeus* crabs were compared, the results indicated that the native *Eurypanopeus* is more inhibited by the insecticide than *Hemigrapsus*.

126.3 MARTINEZ, CM*; ROHLF, FJ; FRISK, MG; University of California, Davis, Stony Brook University; *cmartinez1207@gmail.com*
Extent and Prevalence of Sexual Dimorphism in Skates (Batoidea: Rajoidei)

Accounts of sexual dimorphism in skates are often limited to tooth morphology, alar and malar thorns, and linear dimensions of the body. However, the extent of dimorphism between male and female skates can be quite substantial, involving several morphological features that are vital to the lifestyle of the organism. For this research, we assess the development and divergence of pectoral fin morphologies, review the extent of dimorphism within the endoskeletal system, and discuss the prevalence of dimorphism across skate diversity. Geometric morphometrics of pectoral fin outlines and endoskeletons of two *Leucoraja* species revealed different morphological trajectories for males and females. A rapid change in shape at maturation was identified for males and coincided with skeletal elongation of external reproductive organs, the claspers. Interspecific differences in the magnitude of the morphological transformation appeared to be related to life history variation, namely the relative rates of maturation. Additionally, MicroCT scans of *Fenestraja plutonia* allowed us to identify dimorphism in the pelvic girdle, pectoral girdle, jaws, and neurocranium. Finally, we found evidence of dimorphism in a majority of skate genera, spanning all major subclades. Our understanding of sexual dimorphism in skates remains limited, but this research suggests that divergent morphologies may be intimately linked to the evolution of life histories and reproductive strategies of these fishes.

21.6 MARTING, PR; Arizona State University; *pmarting@asu.edu*
Exploring Causes and Consequences of Colony Personality in the Azteca-Cecropia Mutualism

The symbiosis between *Azteca* ants and *Cecropia* trees is one of the most successful and prominent mutualisms of the neotropics. Ants protect the plant from herbivores and encroaching vines in return for food bodies and nesting cavities. However, little is known about the intricacies of the behavioral ecology of the ant-plant interactions. I conducted a field study and discovered protection behavior varies substantially within the same *Azteca* species due to a colony-level behavioral syndrome (colonies differ repeatably in behavioral traits and these traits are correlated with one another) that is independent of colony size. Furthermore, colony personality type correlates with plant health such that more active, aggressive colonies allow less leaf damage on their host plants. Is this collective behavioral syndrome a fixed, inherent property of the colony or influenced by resource availability? Soil nutrients increase the resources available to the colony via plant growth and food body production. Using greenhouse colony transplants and soil nutrient manipulations, further experimentation is underway to test potential causes of colony-level behavioral syndromes.

53.4 MATHERNE, M.E.*; ZHOU, Y; COCKERILL, K; HU, D.L.; Georgia Institute of Technology; *mmatherne3@gatech.edu*
Swishing tails shoo flies

Biting insects harm mammals through blood loss, loss of resting or feeding time, and disease infection. One way of shooing insects is through swinging one's tail. How does a tail shoo flies? We filmed tails of horses, zebras, and elephants at the Atlanta Zoo. We observe a shooing phase, where the tail swings at its natural frequency to ward off flies. We also observe an attack phase where the tail swings rapidly towards a given target. The attack phase is made possible by actuation at the base of the tail as well as along the muscles in the tail. We build a physical model where a motorized tail can be actuated at multiple points to increase the speed of the attack phase. This study could inspire prosthetics for domestic animals who have lost the tip of their tail due to illness.

P3.223 MATHEW, T*; MASS, S; SUNY New Paltz; *mathewt1@hawkmail.newpaltz.edu*

When Axolotls Metamorphose: The Kinematics of Salamanders That Shouldn't Walk

Axolotls (Ambystoma mexicanum) are neotenic salamanders that do not typically undergo metamorphosis. They remain aquatic when they reach sexual maturity. Very rarely, some axolotls may spontaneously metamorphose into the terrestrial adult form. Due to the rarity of metamorphosis, very little is known about the biology of terrestrial axolotls. We have three of these metamorphosed axolotls in our laboratory. While observing these axolotls interact with their environment, we noticed that they walked in a seemingly clumsy and awkward fashion. This case study uses motion analysis of slow motion video to investigate the kinematics of terrestrial salamander locomotion. We are comparing terrestrial axolotl locomotion to a close relative in the same genus that does normally metamorphose: the tiger salamander (Ambystoma tigrinum). Due to the fact that axolotls are adapted to an aquatic environment, there may be losses and/or changes in developmental processes relative to other terrestrial ambystomoids that would not become phenotypically apparent until metamorphosis. Future studies will examine the neuromuscular anatomy after their natural death to determine whether there are gross anatomical differences between metamorphosed axolotls and tiger salamanders.

52.2 MATLOFF, L*; LENTINK, D; Stanford University; *lmatloff@stanford.edu*

Shape Changing Wings: How Birds Move Their Feathers to Create Aerodynamic Wing Planforms

Feathers enable birds to morph their wings through continuous shapes, allowing them to carefully change their aerodynamic wing planforms to perform nimble maneuvers. We study how skeletal motion and inter-feather friction translates to feather motion in order to better understand the mechanisms for wing shape changes. Using a motion capture camera system, we track the trajectory of the primary and secondary feathers and wing bones in a pigeon, *Columba livia*. We measure the morphing motion of the full wing and the wing after removing the feather vanes. This allows us to see how the motion of individual feathers is defined by the other feathers and the bone structure. We compare motion with intact feathers to motion with the feather vanes removed to assess the effects of friction and direct feather interaction. From these data, we determine a kinematic spring-damper model for feather motion. These findings have implications for designing bio-inspired robots with morphing feather-like mechanisms which could enable agile bird-like maneuvers.

113.4 MATOO, OB*; JULICK, CR; MONTOOTH, KL; University of Nebraska, Lincoln; *omatoo2@unl.edu*

Role of Genetic Variation on the Ontogeny of Metabolism during Development.

Reprogramming of the core metabolism may be necessary during development of many holometabolous insects to generate sufficient energy for maintenance and meet demands of rapid growth. The underlying genetic architecture of an individual during this ontogeny may be crucial, influencing various biochemical and physiological factors that govern metabolic supply and demand. To investigate this, we characterized larval metabolic rate and aspects of glycolytic and mitochondrial physiology across development for a number of natural *Drosophila melanogaster* genotypes, as well as for mitochondrial-nuclear genotypes that combine naturally occurring polymorphisms from different species to generate energetic inefficiencies. The mass-scaling of metabolic rate differed significantly across instars and between genotypes. During development, early instars had significantly higher respiration per unit mass compared to late instars. Interestingly, this was in spite of significantly lower aerobic respiratory capacity of mitochondria in early instars. We also observed a metabolic switch during development away from oxidative phosphorylation to anaerobic ATP production, as measured by accumulation of lactate in the whole body of instars. It has been suggested that this reprogramming in *D. melanogaster* enables individuals to meet bioenergetics and biosynthetic demands of growth. However, there is genetic variation for the extent of metabolic reprogramming in all genotypes. Genotypes with compromised oxidative phosphorylation (OXPHOS) had significantly elevated lactate levels suggesting strong influence underlying genetic variation, including mitochondrial-nuclear genetic interactions (i.e., epistasis). This study demonstrates the diverse metabolic strategies used and the importance of genetic variation on the ontogeny of metabolism.

P2.208 MATSUDA, SB*; GATES, RD; Hawaii Inst. of Mar. Biol.; *shayle@hawaii.edu*

Assessing landscape variability of Symbiodinium across individual coral colonies (Montipora capitata) in Kaneohe Bay

Coral bleaching, the breakdown of the obligate symbiosis between the coral host and its single-celled dinoflagellates, is one of the most evident responses to climate change seen across coral reefs. Different types of *Symbiodinium*, however, are associated with coral hosts that differ in their responses to stress. The reef-building coral, *Montipora capitata*, associates with symbionts in clade C (bleaching susceptible) and clade D (bleaching tolerant) or both (at the species and colony level), and neighboring colonies exhibited very different responses during a bleaching event in 2015. Presently, it is common practice to collect a single sample fragment to identify the types and densities of *Symbiodinium*. This method assumes all *Symbiodinium* exist in equal ratios across the colony, and leaves little room for examining the micro-landscape in regard to host skeletal architecture, flow, and irradiance. This practice impedes our understanding of coral stress response. The dynamic and diverse structural formations of *M. capitata* may provide specialized microenvironments better suited to particular clades, and therefore we hypothesize that there is significant symbiont variability among and within individual colonies. Here, we examine the landscape of symbionts using two approaches: 1) ITS2 sequence diversity at the community level (3 samples/colony, 3 colonies/site) will be assessed from ten locations around Oahu and 2) ITS2 sequence diversity at individual level assessed in ~50 samples per colony distributed evenly across the five colonies from Kaneohe Bay. Sampling points will be selected using meshes created through structure-from-motion photogrammetry. Assessing the landscape variability of *Symbiodinium* is a necessary step in examining the ecological advantages that symbionts contribute to the holobiont's ability to acclimatize and adapt to future climate conditions.

P1.149 MATTERN, B*; HA, D; COUGHLIN, B; UNF;
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Potassium sorbate inhibits growth of a common species in the human gut microbiome, Enterococcus faecalis

Food additives often have useful antimicrobial properties, which decrease the risk of ingesting pathogens in products such as dairy. Consumed food additives are eventually metabolized or excreted, but may impact the alimentary canal and the human gut microbiome during the digestive process. If preservatives inhibit the growth of unwanted bacteria in food products, then it is reasonable to infer that they can affect the growth of our microbiome as well. This study utilized a commensal species of bacterium from the human gut, *Enterococcus faecalis*, to test the hypothesis that exposing this bacterium to potassium sorbate (PS), will inhibit its growth. This preservative is classified as GRAS by the FDA, and is metabolized by fatty acid oxidation. To test its effects on *E. faecalis*, the bacteria were cultured anaerobically using the Hungate tube method, simulating human gut conditions, and then exposed to varying concentrations of potassium sorbate close to the FDA consumption recommendations. Growth curves were generated using turbidity via spectrophotometric measurements, and a 43% decrease in growth was observed during the exponential growth phase, 4 hours post-inoculation (alpha= 0.05, P= 1.37 x 10^{-5}). These results support the hypothesis that this preservative inhibits bacterial growth, and future experiments are aimed at testing its effects on other common species. The human microbiome has quickly fought its way to the spotlight of the scientific community for its implications on metabolism and immune response; however, the current amount of research investigating unintended consequences of exposure to preservatives on this microbiome is lacking. As our knowledge of these implications increases, regulatory agencies such as the FDA may need to adjust their recommendations of additives allowed in food products.

97.6 MATTHEWS, M*; SPONBERG, S; Georgia Tech;
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Free Flight Tracking in Unsteady Flow: Probing Hawkmoth Maneuverability in an Artificial Flower Wake

Birds, insects, and many other animals have developed mechanisms to maintain hovering flight to feed from flowers across varied biological length scales and environments. Although recent studies have examined flight performance in unsteady wind, few examine these flight mechanisms during a prescribed task. Understanding how flying insects feed from flowers in nature requires coupled analysis of the effects of unsteady flows in the wake of an object and flight maneuverability. We investigate the dynamics of insect maneuverability in an unsteady wake by having *Manduca sexta*, known to hover while feeding, track a 3D-printed robotic flower in a wind tunnel and compare to results from previous experiments in a still air flight chamber. Overall, moths tracking laterally in the flower wake with a freestream velocity of 0.7 m/s perform worse, and do so at earlier frequencies, than moths tracking in still air suggesting that they track in a narrower frequency band in an unsteady flow environment. Smoke visualization of the flower wake shows vortex shedding at approximately 3-4 Hz with a localized region of unsteady flow dominating the hovering location of the moths. Aerodynamic interactions between the moth and the flower wake may require the animal to make more small corrections to maintain a stable feeding position, thus using more mechanical power than tracking in still air. It is also possible that the flower wake affects the stability of the leading-edge vortex bound to the wing, leading to changes in flight stability since the LEV is responsible for generating most of the lift during the wingstroke. In general, flying in unsteady wind seems to decrease maneuverability; the hawkmoths track effectively in a smaller frequency range and use more mechanical power when their tracking performance is worse.

P1.153 MATTHEWS, CR*; RIDDELL, EA; APANOVITCH, EK; RICE, CD; SEARS, MW; Clemson University;
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Thermal stress induces melanin production in a lungless salamander

Animals that live in variable climates are often exposed to stressful conditions. Variable temperatures can be a harmful stressor due to the production of tissue-damaging chemicals, such as reactive oxygen species. Melanin production is one means by which animals protect tissues from cellular damage caused by exposure to warm temperatures. We investigated the immunological and physiological responses to temperature and humidity as stressors in an abundant terrestrial salamander (*Plethodon metcalfi*). We exposed individuals to cycling temperature and humidity treatments over a period of four weeks in the laboratory. Nocturnal activity was simulated by moving salamanders to open-air containers that exposed individuals to cycling temperatures and vapor pressure deficits (VPDs). We maintained the same VPDs across temperature treatments to ensure temperature and humidity were not confounded in the study. We sampled blood smears to assess the stress response and production of melanin in the liver before and after the experiment. We tested for a generalized stress response by measuring neutrophil to lymphocyte (NL) ratios in the blood smears. Melanin production increased dramatically across the experiment, with low levels of melanin at the beginning and high levels at the end of the experiment. In response to temperature, individuals produced more melanin under warm treatments than individuals from cool treatments. The NL ratios indicated equally low levels of stress across all treatments, suggesting an absence of a stress response across the treatments. We also found very limited evidence of liver damage, such as irregular arrangement of liver parenchyma and hepatocytes. These results suggest that physiological responses, such as the production of melanin, might be an important response involved in limiting stress under warm temperatures.

15.5 MATZ, MV*; DIXON, GB; TREML, EA; University of Texas at Austin, University of Melbourne; *matz@utexas.edu*

Adaptive demographic pathways for Great Barrier Reef corals

Global warming is expected to result in preferential survival of coral migrants from warmer to cooler locations as well as in overall decline in genetic diversity due to bleaching-related mortality. We sought to quantify these trends using population genomics and biophysical modeling. We have genotyped five populations of the common reef-building coral Acropora millepora spanning the latitudinal extent of the Great Barrier Reef (GBR) using 2bRAD (~25,000 SNPs genotyped at >98% accuracy). These data were analyzed using non-equilibrium coalescent-based methods to estimate pairwise immigration rates and historical effective population sizes. Our biophysical model predicted coral immigration rates in the absence of spatially varying selection, with 1km resolution across the GBR. Genomic data revealed strong bias towards preferential spread of immigrants from lower to higher latitudes; however, so did the biophysical model, indicating that this bias was attributable to local currents rather than the differential migrants' survival. We did not see evidence of recent decline in genetic diversity: the most recent expansion and contraction trends of A. millepora populations date back several thousand years, prior to the anthropogenic global warming. Our results give hope for coral persistence under future climate: their genetic variation has not yet been affected and the observed southward migration trend will facilitate the spread of heat-tolerant genotypes from low-latitude locations throughout the GBR.

P1.117 MAURO, AM*; TORRES DOWDALL, JR; GHALAMBOR, CK; Colorado State University, Univerisitat Konstanz; *Alexander.Mauro@colostate.edu*

The Impact of Competition and Salinity on Life History Traits of Two Sympatric Euryhaline Fish

An unresolved question in integrative biology is why natural selection does not favor the evolution of greater environmental tolerance and the expansion of geographic ranges. Common hypotheses often invoke a role for competition on range limits, but few l examples exist in nature. Here we test how salinity and competition impact life history traits in two closely related euryhaline fish; *Poecilia reticulata* and *Poecilia picta*. Both species can tolerate and reproduce in brackish and fresh water, yet on Trinidad the species segregate along a salinity gradient. *P.reticulata* is found alone in upstream freshwater sites, while *P. picta* is found alone in downstream brackish water sites. Both species coexist in lowland freshwater streams near the transition zone with brackish water. To test how competition and salinity might interact to prevent *P.picta* from moving upstream and *P. reticulata* from expanding its range into brackish water, we measured how fecundity, offspring size, and reproductive allocation change where the species do and do not co-occur. We found that offspring size increases for both species where they coexist. Larger offspring sizes have been suggested to be a strategy that can ameliorate the fitness costs of competition. However, the increase in offspring size came with no apparent cost in the other traits measured, as reproductive allocation and offspring number remained unchanged for both species. These results suggest competitive interactions between species may interact with salinity to shape range limits. Further, our results highlight why a broad, integrative approach incorporating both abiotic and biotic factors is needed to explain range limitations.

P1.161 MAVROIDIS, SM*; MAINWARING, WJ; STRAITS, SK; YANIK, BM; NICKLES, NE; Univ. of Mount Union; *mavrois@mountunion.edu*

The Effect of Incubation Temperature on Embryo Metabolism and Hatchling Morphology of Northern Bobwhite Quail (Colinus virginianus)

In many oviparous species, incubation temperature plays an important role in the energy use of developing embryos and their hatching success. Although birds are endothermic after hatching, embryos generate little body heat and thus metabolism is closely tied to incubation temperature. For several decades, bobwhite quail populations have steadily decreased throughout most of their range. Loss of habitat and unfavorable nesting conditions (e.g., temperature) are likely causes. This study examined the effects of temperature on developing Northern Bobwhite quail embryos (*Colinus virginianus*). Eggs were incubated at one of four temperatures (35.5C, 36.5C, 37.5C, 38.5C). After the first week of incubation, metabolic rates (oxygen consumption) were recorded twice weekly from randomly selected eggs at each treatment temperature. Metabolic rate was positively correlated to incubation temperature and time. Rates increased significantly across the incubation period and embryos at higher temperatures had significantly greater metabolic rates than those at lower temperatures. Hatching rates decreased with decreasing temperatures while time to hatching decreased with increasing incubation temperature. Chick yolk-free dry mass and tarsus length increased while residual yolk dry mass decreased with increasing incubation temperature. Egg dimensions are good predictors of chick mass, although egg width has a stronger correlation than does egg length to chick mass. In summary, incubation temperature effects a developing embryo's metabolism and thus energy use, which may ultimately determine hatching morphology and other life history traits.

89.5 MAY, MA*; BISHOP, KD; RAWSON, PD; University of Maine, Husson University; *melissa.may@maine.edu*

Linking Patterns of Gene Expression to Phenotypic Responses in Larval and Juvenile Blue Mussels, Mytilus edulis, Exposed to Low Salinity Stress

Blue mussels (*Mytilus edulis*) are a keystone species in coastal marine communities. Protracted decreases in nearshore salinity as a result of global climate change pose a threat to the survival, distribution, and abundance of mussels; accurate predictions about how mussel populations will be impacted by changing salinity requires an improved understanding of how this species responds to salinity stress. Mussels are osmoconformers and numerous studies have shown that adult mussels mitigate low salinity stress through regulation of intracellular osmolytes, principally through efflux of free amino acids. However, little is known about the genetic regulation of this osmotic stress response in mussels, and thus we have incomplete knowledge of the mussels' capacity to acclimatize or adapt to a changing environment. Furthermore, mussels have a complex life-history; larvae are generally more sensitive to environmental stressors but few, if any, studies have investigated the degree to which the osmotic stress response is conserved among life history stages. Based on microarray data, we have selected two genes that are differentially expressed in adult mussels exposed to hyposaline stress and likely play an important role in the regulation of free amino acids. Using rt-qPCR, we have monitored the time-specific variation in expression of these genes in adult and larval mussels exposed to a 33% drop in salinity for 72 h. Concurrently, we used NMR spectroscopy to examine variation at the cellular level by measuring changes in the relative concentrations of free amino acids. Our results indicate that the interactions between gene expression and cellular-level phenotype during hypoosmotic exposure are complex and that the responses are stage-, tissue-, and time-specific.

107.2 MAYBERRY, HW*; JAKOBSEN, L; WAHLBERG, M; SURLYKKE, A; RATCLIFFE, JM; University of Toronto, Mississauga, University of Southern Denmark; *heather.mayberry@mail.utoronto.ca*

Echolocation in bats and porpoises hunting alone and in pairs

Approximately 1000 species of bat and 80 species of toothed whales are known to use echolocation to detect and track prey. While the basic function and phases of echolocation (search, approach and terminal buzz) are similar in both laryngeal echolocating bats and toothed whales, it is currently unclear whether similarities between Chiroptera and Cetacea extend to group situations. The influence of conspecifics on echolocation signals, for example, has been widely studied in bats, but is relatively lacking with respect to toothed whales, including porpoises. Using multi-microphone arrays and multi-hydrophone arrays, we recorded the calls/clicks produced by Daubenton's bats and harbour porpoises, respectively, while they hunted insects and fish either alone or with a conspecific. Some of the call/click parameters we measured included source level (dB re 1 μPa pp), peak frequency, +/- 10 dB bandwidth, signal duration and inter-click interval (or call period). Based on previous research, we expect that bats foraging in pairs will produce calls with shorter durations, longer call periods and more variable peak frequencies compared to foraging alone. Because porpoises are facing similar constraints and acoustic clutter when they forage in groups, we expect to see similar changes in echolocation click parameters in harbour porpoises. Deviations from these patterns could provide information regarding the ability or likelihood of porpoises to engage in jamming avoidance responses or clutter responses when hunting with conspecifics.

118.2 MAYERL, CJ*; YOUNGBLOOD, JP; RIVERA, G; VANCE, JT; BLOB, RW; Clemson University, Arizona State University, Creighton University, College of Charleston; *cmayerl@clemson.edu*

Stability vs maneuverability in freshwater turtles

In aquatic environments, increased locomotor stability can decrease energetic expenditure by animals, whereas maneuverability is useful for successfully navigating complex habitats. Many morphological features of animals might improve performance in either of these functions. In our previous work on swimming in turtles, we determined that the pelvis is mobile in one of the two major lineages, the cryptodires, but is immobile in the other major lineage, the pleurodires. We sought to test whether these differences in pelvic fusion translated to differences in aquatic stability and maneuverability in these lineages. To do this, we filmed turtles with high-speed video after training them to chase a prey stimulus affixed to a robotic 2-DOF gantry, which ensured that turtles were either swimming straight (to measure stability), or turning at reproducible angles (to measure maneuverability). We tested swimming stability in a flow tank using water speeds ranging from still to 2 BL/sec, and collected maneuverability data in still water. In stability trials, we found that pitch and heave increased with faster flow speed in cryptodires, whereas sideslip and yaw increased at greater flow speeds in pleurodires. Cryptodires consistently had greater limb excursions for both fore and hind limbs, but swam at slower speeds than pleurodires. However, maneuverability also differed between the two lineages. Our results suggest that the structural differences between cryptodire and pleurodire turtles may have significant impacts on their locomotor performance, and may contribute to the differing ecological distributions of species in these lineages.

P2.24 MAYOL, M*; IYENGAR, EV; Muhlenberg College; *mm248692@muhlenberg.edu*

Climate change and stress-eating slugs: comparative responses of an invasive and native species

Climate change is expected to increase average temperatures and alter precipitation across the world, which should have disproportionate impacts on ectothermic animals. If metabolic rates increase with temperature, multiple cascading alterations can occur in addition to increased food consumption such as elevated movement rates and distances, growth, and fecundity. However, most ectotherms have an optimal temperature above which they suffer physiological stress unless they can shift their thermal tolerance range. We observed the effects of temperature on the feeding rate of two terrestrial slug species: *Ariolimax columbianus* (banana slug, native to Pacific Northwest) and *Arion rufus* (invasive slug, native to Europe). Individuals of both of these nocturnal species were exposed to 5°C (average spring night temperature), 10°C (average summer night temperature), and 20°C to determine the impact of temperature on consumption rates. We conducted these experiments in two summers: one with aberrantly high temperatures and drought, another with more typical temperatures and mild drought. We also investigated whether short term (7 day) exposure to either 5°C or 20°C before testing allowed the animals to acclimate and elevate their experimental feeding rates. Additionally, we tested the effect of humidity and soil moisture level on feeding rates. Because slugs are extremely sensitive to desiccation and regulate most moisture gain/loss through the foot, we expected feeding rate to increase with humidity and soil moisture content. Comparing results across two species of slugs, especially as one is an invader and the other is a native species with a highly restricted range in terms of biogeography and microhabitat, will provide insight as to how anticipated climate changes will impact the local molluscan fauna, as well as perhaps local ectotherms in general.

P1.91 MÉNDEZ-NARVÁEZ, J*; WARKENTIN, KM; Boston University, Boston; *javier0620@gmail.com*

Nitrogen Excretion Plasticity in Early Life Stages of Aquatic- and Terrestrial-Foam-Nesting Frogs: a Potential Mechanism Facilitating Reproductive Colonization of Land

Phenotypic plasticity is hypothesized to play a role in evolution and facilitate colonization of new environments. In frogs, this may have been an important step in the evolution of terrestrial egg-laying. A major physiological change in terrestrial tetrapods was the shift to excreting more costly, less toxic urea, as an adaptation to avoid ammonia toxicity under water constraints. Urea is the main form of nitrogen waste excretion in adult frogs, but is known from embryos or tadpoles in few species. We hypothesize that these stages have evolved adaptive plastic responses to transient terrestrial conditions, including N-excretion plasticity. We studied early life stages of two closely related, sympatric species in the family Leptodactylidae. *Engystomops pustulosus* lays eggs in aquatic foam nests, in pools that sometimes dry, and *Leptodactylus fragilis* makes foam nests in terrestrial burrows that usually flood later. We manipulated water availability and quantified ammonia and urea excretion by embryos and hatchling tadpoles in nests of both species, to test if facultative shifts from ammonia to urea excretion occur in response to desiccation risk. We kept aquatic foam nests of *E. pustulosus* either above water or on a dry substrate, We kept foam nests of *L. fragilis* in soil with water content matching or 50% less than field conditions. *E. pustulosus* foam nests over water accumulated only ammonia, but some nests on dry substrate also contained urea. In contrast, *L. fragilis* nests accumulated both ammonia and urea at both hydration levels tested. Our results indicate that urea excretion can occur in the aquatic foam nests (the ancestral condition) as a plastic response to drying, but it may be fixed in the derived terrestrial foam nests.

44.6 MüLLER, M. S. *; VYSSOTSKI, A. L. ; YAMAMOTO, M. ; YODA, K.; Graduate School of Environmental Studies, Nagoya University, Institute of Neuroinformatics, University of Zurich/ETH Zurich, Department of BioEngineering, Nagaoka University of Technology; *martina.muller9@gmail.com*

Fight-or-flight Responses in a Free-living Seabird Consistently Differ between Individuals, Vary with Body Condition and are Dominated by a Decrease in Parasympathetic Activity

The fight-or-flight response is a highly conserved stress response in vertebrates that occurs via the autonomic nervous system: a decrease in parasympathetic (PNS) activity, which promotes self-maintenance 'rest and digest' processes, and an increase in sympathetic (SNS) activity, which prepares an animal for danger. The PNS and SNS mostly act on different parts of the body (though the heart is innervated by both) and can be regulated independently, yet until now, most studies of autonomic stress responses in non-model species focused only on the SNS response. We used non-invasive external electrocardiogram loggers to quantify heart rate (HR) and heart rate variability (HRV) indexes that reflect PNS and SNS activity in the streaked shearwater (*Calonectris leucomelas*), a pelagic seabird. We quantified PNS and SNS responses to the stress of handling, and during recovery in the nest burrow. We show for the first time in a free-living animal that the fight-or-flight response was mediated primarily by a rapid decrease in PNS activity with only a short and small increase in SNS activity. Individuals consistently differed in their fight-or-flight responses within and across years. Birds with a lower body mass index had higher PNS activity and lower HR suggesting that birds with lower energy reserves may maintain high PNS activity to minimise energy expenditure. Using HR and HRV to measure autonomic activity is an effective non-invasive method for studying stress physiology in free-living animals.

28.3 MCANULTY, SJ*; NYHOLM, SV; University of Connecticut;
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Judging a bacterium by its cover: differential hemocyte binding in the squid-vibrio symbiosis

Euprymna scolopes engages in a specific symbiosis with *Vibrio fischeri*, a bioluminescent bacterium that lives in a specialized light organ in the squid. The cellular immune system of *E. scolopes* consists of one type of blood cell, the hemocyte. Previous work showed that hemocytes from colonized adult *E. scolopes* bind closely-related vibrio species, *V. fischeri* and *V. harveyi*, at low and high levels respectively. Curing the adult light organ significantly increased hemocyte binding to *V. fischeri*, suggesting that colonization influences hemocyte recognition of the symbiont. In order to understand hemocyte binding dynamics with bacteria, hemocytes from adults were isolated and co-incubated with *V. fischeri*, *V. harveyi*, *Photobacterium leognathi*, and polystyrene beads. Live cell imaging using confocal microscopy was used to quantify the binding and release of bacteria by hemocytes. These experiments revealed that over a period of 30min, hemocytes bound all species tested, but after binding released a significantly higher percentage of *V. fischeri* (60%) compared to *P. leognathi* (41%), *V. harveyi* (12%) and beads (2.7%). Furthermore, a *V. fischeri* mutant lacking an outer membrane protein (OmpU) was released less frequently (34%) compared to wild type, suggesting that OmpU or bacterial products that pass through this porin may play a role in facilitating release from hemocytes. These data, along with previous results, suggest that there are both host and symbiont mechanisms to ensure that *V. fischeri* evades clearance by the host's cellular innate immune system. Future work will focus on understanding host cell-surface pattern recognition receptors that may be involved with binding of symbiotic and non-symbiotic bacteria, possibly through the detection of microbe-associated molecular patterns.

84.2 MCBRAYER, L*; KEROUAC, L; MCELROY, E; Georgia Southern, College of Charleston;
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Substrates and settings: quantifying locomotor performance in functional and ecological contexts

Animal locomotion has been studied extensively in the lab to understand the fundamental mechanisms required for stability, propulsion, endurance, and speed. Yet, quantifying and comparing these same types of parameters is much more difficult in the field and thus remains uncommon. We endeavor to shed light on several well-studied aspects of locomotion using a model species moving both in the lab on unnatural substrates and in the field on natural substrates. In the field, we measured the length of over 600 strides of a small lizard *(Aspidoscelis sexlineata)* to examine movement in a natural context. Furthermore, we measured escape velocity on a subset of animals and compared these data to sprint velocities captured in the lab on a two-meter photo-celled timed track. From lizard spoor, we found that stride length is not related to incline, heading, or path length, but that escape speed was related to path length, incline, and heading. We will present data on sprint and walking performance, as well as compare acceleration capacity on an artificial surface vs a nature sand substrate.

56.6 MCCAIN, SC*; KOPELIC, S; STAUDHAMMER, C; EARLEY, RL; The University of Alabama, Tuscaloosa;
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A brackish water specialist that prefers freshwater: the case of the mangrove rivulus fish

Within heterogeneous environments, mobile species are expected to occupy habitats that maximize fitness. However, competitors and predators might preclude individuals from persisting in these habitats, leading to situations in which a species exists at high abundance in suboptimal environments. Mangrove rivulus fish, *Kryptolebias marmoratus*, inhabit mangrove ecosystems where salinities range from 0 - 65 ppt but are most often collected at 25 ppt. We examined rivulus' salinity preference under controlled conditions and in the absence of predators and competitors. We exposed fish to a salinity gradient with chambers containing salinities of 5, 15, 25, 35 and 45 ppt for 8 hours. We defined preference as the salinity in which the fish spent the majority of their time during the trial. To determine whether preferences were repeatable, each fish experienced three trials. Rivulus spent a greater proportion of time in lower salinities (5, 15 ppt), which indicates that, when given the opportunity, rivulus select habitats of lower salinity than they occupy in the wild. We also determined the salinity at which rivulus would lay their eggs by exposing fish to a salinity gradient for 2 weeks. Rivulus showed a significantly greater probability of laying eggs in low salinities compared to control (25 ppt) or high salinities. Evidence from this study suggests that although rivulus can tolerate a wide range of salinities, they prefer salinities approaching freshwater. These results raise questions about factors that prevent rivulus from occupying lower salinities in the wild, whether higher salinities impose energetic costs, and whether fitness changes as a function of salinity.

P3.25 MCCARTER, AL*; TOMPKINS, EM; ANDERSON, DJ; MANESS, TJ; Louisiana Tech University, Wake Forest University;
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Induction and maintenance of immunological memory in a long-lived seabird

Life history theory predicts that short-lived species will prioritize current reproductive efforts over self-maintenance functions to a greater extent than will long-lived species. These strategies are thought to maximize parental fitness for each life history mode. Therefore, long-lived species ought to invest heavily in immune defense, particularly the defenses of the acquired immune system. Yet little is known about the induction and maintenance of immunological memory in wild species. We are investigating the primary and secondary immune responses of Nazca Boobies, *Sula granti*, a long-lived seabird in the Galápagos Islands, Ecuador. To assess their primary immune responses, we collected blood samples before and after injecting the birds with a harmless antigen, keyhole limpet hemocyanin, known to stimulate a specific immune response in vertebrates. We repeated the process after three months, and then nine years later, to investigate their immune memory responses in short- and long-term time frames. We are using an ELISA assay to identify specific antibodies to the antigen and see if the birds are able to maintain immune memory cells over time.

6.7 MCCARTHY, JB*; VENDETTI, JE; KRUG, PJ; VALDéS, ÁA; California State Polytechnic University, Pomona, Natural History Museum of Los Angeles county, California State University, Los Angeles; *jbmccarthy1001@gmail.com*

The slug within the bivalve: Reconciliation of shell-based taxonomy and molecular data in Juliidae (Heterobranchia: Sacoglossa)

Juliidae is a member of the order Sacoglossa, a clade of herbivorous heterobranch gastropods. Juliidae has a complex taxonomic history derived from the fact that these gastropods have bivalve shells. The current taxonomy of Juliidae is largely based on shell morphological traits and to a certain extent on internal and anatomical traits, such as radula and reproductive anatomy. Based on these data, Juliidae is considered to have two extant genera, *Berthelinia* and *Julia*, both with pan-tropical distributions. For this study a species-level molecular phylogeny of Juliidae has been produced using a combination of three genes, two mitochondrial (CO1, 16S), and one nuclear (H3). Based on Recent shells and fossil shells from the literature, a principal component analysis (PCA) was produced using geometric morphometric techniques to quantify and compare the shell morphologies. Based on preliminary molecular results, two clades are resolved agreeing with the two extant genera. The morphometric data will be integrated with the molecular phylogeny using comparative methodologies.

P1.78 MCCLAIN, MA*; DALY-ENGEL, TS; University of West Florida; *mam171@students.uwf.edu*

Local Connectivity and Relatedness Analysis of Tiger Sharks between the Gulf of Mexico and West Atlantic

Shark dispersal for the purposes of reproduction is generally poorly understood, including that of Tiger Sharks (*Galeocerdo cuvier*), a large, circumglobal, coastal-pelagic species. Learning more about the dispersal patterns of apex predators, like the Tiger Shark, will allow for greater understanding of the conservation measures needed to protect this species. To gain insight into the reproductive evolution of these sharks, we have collected *G. cuvier* tissue samples from five sample sites in the Gulf of Mexico and West Atlantic. We use highly polymorphic microsatellite DNA fragment analysis to examine relatedness of individuals within and across ocean basins, and use assignment testing to identify potential distribution corridors and critical habitat. Based on dispersal patterns observed in other large coastal shark species, we hypothesize that there will be shallow structure between the different sample sites due to various geographic, environmental, and reproductive barriers. We further hypothesized that this structure will be male-biased, reflecting the female dependence on coastal nursery habitat.

106.3 MCCLEARY, RJR*; PANDI, BP; JHA, N; SATHYAN, N; KINI, RM; Utah State University, Vellore Institute of Technology, Indian Institute of Technology-Kanpur, University of Mumbai & Department of Atomic Energy, National University of Singapore; *19venom84@gmail.com*

Surprise Presence of a Membrane-Bound Protein: Characterization of a Neprilysin from the Venom of the King Cobra (Ophiophagus hannah)

Previous transcriptomic analysis of the venom gland of the king cobra (*Ophiophagus hannah*) yielded a gene for a protein similar to neprilysin, along with many other toxin genes. Although all known venom proteins are secreted into the venom, this gene did not contain a signal peptide, indicating that it is not secreted. Rather, it contained a transmembrane domain, which indicates that it is an integral membrane protein. However, proteomic analysis indicated the presence of this protein in the venom of the same animal. We isolated and purified this protein using size exclusion and anion exchange chromatography and verified its presence through tandem mass spectrometry of peptides obtained by digestion with trypsin and Glu-C. Overall, we were able to obtain greater than 75% coverage of the sequence of the protein, and this coverage included portions N- and C-terminal to the transmembrane domain. We further utilized the protein at various stages of purification for assays against atrial natriuretic peptide, a natural substrate of neprilysin. Intraspecific genomic and transcriptomic sequence analysis showed the sequences to be identical, and exon comparisons with other genomic sequences showed strong similarities. Overall, these data indicate that the protein found in the venom is identical to that found in other tissues, and that the protein is neprilysin. This represents the first description of a membrane-bound protein isolated from snake venom.

S2.5 MCCLELLAND, G.B.*; LYONS, S.A.; ROBERTSON, C.E.; McMaster University; *grantm@mcmaster.ca*

Exercise fuel use in mammals: Conserved patterns and evolved strategies for aerobic locomotion.

Effective aerobic locomotion depends on adequate delivery of oxygen and an appropriate allocation of metabolic substrates. The pattern of metabolic substrate use during exercise follows a predictive pattern in lowland native mammals. We have found that in two highland lineages of mice (*Phyllotis* and *Peromyscus*) this fuel use pattern is shifted to a greater reliance on carbohydrates to power locomotion. However, there is variation between lineages and in different populations in the importance of phenotypic plasticity in the expression of this metabolic phenotype. Moreover, this metabolic phenotype during exercise is independent of running aerobic capacity but can also be independent of thermogenic capacity. For example, wild-caught mice from a highland population of deer mice *Peromyscus maniculatus* maintains higher maximum cold-induced oxygen consumption in hypoxia than lowland congenerics, but this is supported by high rates of lipid oxidation. This is reflected in the consistently higher activities of oxidative and fatty acid oxidation enzymes in the gastrocnemius of highland compared to lowlanders. In contrast, the activities of enzymes involved in glycolysis and exercise fuel use showed significant phenotypic plasticity in muscle with hypoxia acclimation in highland mice. This suggests that while a fixed trait in muscle aerobic capacity may reflect the stable low oxygen conditions at high altitude, muscle capacities for substrate oxidation may be more flexible to match appropriate substrate use with changing energetic demands. How shivering thermogenesis and locomotion potentially interact in the matching of muscle metabolic capacities to appropriate substrate use is unclear. Perhaps it is possible that shivering serves as "training" to ensure muscles have the capacity to support locomotion or *visa-versa*.

P2.185 MCCLELLAND, SJ*; BENDIS, RJ; WOODLEY, SK; RELYEA, RA; Duquesne University, University of Pittsburgh at Johnstown, Rensselaer Polytechnic Institute; *mcclell2@duq.edu*
Pesticide-resistant Zooplankton Do Not Buffer the Effects of Chlorpyrifos on Amphibian Neurodevelopment
Pesticide use affects aquatic communities directly and indirectly. Previous work showed morphological and neurodevelopmental changes in tadpoles exposed to the pesticide chlorpyrifos (CPF; 5 and 20ppb) in mesocosms. It is unclear if effects resulted from direct CPF exposure or from trophic interactions due to a decline in zooplankton. This study aimed to determine if CPF affects brain anatomy when the trophic environment is not altered and to determine the extent of protection that pesticide-resistant zooplankton have on an aquatic community. *Lithobates pipiens* tadpoles were exposed to 0ppb or 1ppb CPF and then reared to metamorphs in mesocosms containing either CPF-resistant or CPF-sensitive *Daphnia pulex* zooplankton. In mesocosms with CPF-sensitive zooplankton, relative body length and head width of metamorphs was reduced; the reverse was found in metamorphs from mesocosms with CPF-resistant zooplankton. Exposure to CPF resulted in metamorphs with relatively wider optic tectum, medulla, and diencephalon compared to controls, regardless of whether zooplankton was CPF-resistant. Hence, survival of zooplankton in the presence of CPF stabilizes the food web and can have buffering effects on metamorph body shape, but protecting the food web did not mitigate the effects of CPF on metamorph brain morphology. This study provides evidence of the dangers of exposure to low, ecologically relevant doses of organophosphorous pesticides on neurodevelopment in vertebrates.

P1.217 MCCONKEY, RP*; INGLE, DN; PORTER, ME; Florida Atlantic University; *rmcconkey2013@fau.edu*
Viscoelastic properties of mineralized shark vertebrae
Amplitude and frequency of lateral undulation during swimming varies greatly across shark species. As animals swim through the water, the vertebral column behave as a spring and a break mechanically loading mineralized cartilaginous vertebrae with each tailbeat. Previous research has quantified mechanical properties of shark vertebrae from under the first dorsal fin. To better understand mechanical function in vertebrae of a swimming sharks, we conducted compression tests on centra from five regions along the vertebral column in two species with dramatically different swimming styles: angel (Squatina squatina) and mako (Isurus oxyrinchus) sharks. In each region, we quantified the stiffness (resistance to compression) and maximum strength (largest stress) of the shark centra at three displacement rates: 10%, 1%, and 0.1%. We dissected three adjacent vertebrae from five regions along the column. Vertebral arches were removed with a scalpel and centra were stored in elasmobranch Ringer's solution before testing. Three adjacent vertebrae were measured at each region and their lengths averaged to determine strain rates at 10% 1% and 0.1%. Vertebrae were tested to 1kN on an Instron. In these species, we found that stiffness did not vary across region, but stiffness was greater at the slowest strain rate. We also found that the total average stiffness is higher in angel sharks. These values highlight the viscoelastic nature of the mineralized cartilaginous material found in shark vertebrae, and also that mechanical properties vary widely in animals utilizing different swimming strategies.

29.4 MCCORD, CL*; WESTNEAT, MW; University of Chicago; *charlene.l.mccord@gmail.com*
Phylogenetics, morphometrics and cranial biomechanics of butterflyfishes and angelfishes (Chaetodontoidea)
Angelfishes and butterflyfishes (collectively chaetodontoid fishes) are among the most economically and ecologically important, as well as charismatic, members of circumglobal tropical coral reef ecosystems. Our recent phylogenetic analyses show a strong sister-group relationship for the two families in the context of other scaly-finned "sqamipinne" fishes. By combining techniques from phylogenetics, geometric morphometrics, and computational biomechanics, we sought to quantitatively explore the biodiversity of butterflyfish and angelfish cranial and body shape features across densely sampled species phylogenies for the group. Phylomorphospace results show that size, phylogeny and diet have affected shape evolution in angelfishes and butterflyfishes, that pomacanthids and chaetodontids occupy distinct regions of phylomorphospace, and that skull shape evolution has direct functional implications. Using cranial morphometrics and computational modeling, we set out to characterize the biomechanical consequences of the intramandibular jaw joint (IMJ) that is present in many species in these two families. Modeling suggests that the IMJ is usually associated with lower bite force, but confers an increased ability to vary the vector of force application of the lower jaw. Our data reveal significant instances of both convergent and divergent evolution of morphological and biomechanical features during the radiation of chaetodontoid fishes, with morphospace groupings significantly associated with ecological traits.

P3.39 MCCOWIN, MF*; ROUSE, GW; Univ. of California, San Diego; *mmccowin@ucsd.edu*
Iphionidae (Aphroditiformia, Annelida) from Pacific Hydrothermal Vents
The scaleworm family Iphionidae consists of five genera. Of these, *Thermiphione* has two accepted species, both native to hydrothermal vents in the Pacific; *Thermiphione fijiensis* (*West Pacific* vents) and *Thermiphione tufari* (*East Pacific Rise* vents). *Iphionella* is also known from the Pacific, and has two recognized species; *Iphionella risensis* (*East Pacific Rise* vents) and *Iphionella philippinensis* (*West Pacific* deep sea). In this study, phylogenetic analyses of Iphionidae from hydrothermal vents across the Pacific were conducted utilizing mitochondrial (COI and 16S rRNA) and nuclear (18S and 28S rRNA) genes. This revealed a new species in this clade, corroborated by additional morphology. The analyses also showed the paraphyly of *Thermiphione* with respect to *Iphionella*, and various taxonomic solutions are discussed.

131.7 MCCOY, MW; East Carolina University; *mccoym@ecu.edu*
Resource availability and prey growth dynamics determines the outcome of size-structured predator-prey interactions
Most animals undergo substantial changes in body size and morphology during ontogeny that can influence many aspects of ecological performance. For example, body size variation can strongly influence predator-prey interactions and drive patterns of size structure in prey populations and strongly influence long-term population dynamics and community structure. Predator consumption rates are commonly unimodal functions of prey size. Prey may therefore pass through windows of vulnerability to size specific predators as they grow through ontogeny. Prey growth rates can therefore be strong determinants of prey survival probability. Prey growth rates are in turn driven by resource availability. Consequently, resources may impose bottom up control on the outcome of size structured predator-prey interactions. I will present experimental and simulation results demonstrating how prey growth and resource availability affects the interactions between red-eyed tree frog tadpoles and two different size-limited predators--dragonfly nymphs and giant water bugs.

139.4 MCCOY, K/A*; BLAKE, B/E; TRAN, T; East Carolina University, University of North Carolina at Chapel Hill; *mccoyk@ecu.edu*
Fetal Sex Hormone Exposure Programs Autism-Like Behavior in the Rat Model.
Autism spectrum disorder (ASD) is a neurodevelopmental disorder that is broadly characterized by repetitive behavior, and atypical social behavior and communication. It also commonly presents with anxiety and hyperactivity. ASD occurs 1 in 68 children in the U.S. and is five times more common in males than in females. The reason for this sex bias is unknown. The "extreme male brain theory" hypothesizes that a hyper-androgenic fetal environment aberrantly hyper-masculinizes the developing brain, resulting in an autistic behavioral phenotype. Evidence for this includes correlational findings that sexually dimorphic brain regions that are larger in males are even more enlarged in autistic patients, and increased fetal testosterone concentrations increase risk for ASD. Androgens impact brain development by binding androgen receptor (AR) as testosterone or its metabolite 5α-dihydrotestosterone to elicit AR-dependent responses, or testosterone can be converted to estradiol, which binds to estrogen receptors (ER) to elicit ER-dependent responses. We test whether prenatal overexposure to AR- or ER-specific testosterone metabolites induces ASD-like behavior in the rat, and if effects occur more often in males. We show estradiol consistently induces autistic-like behavior in male but not female rats, similar to the sex bias seen in humans with autism. Our findings provide key insights toward establishing the link between fetal endocrine environment and autism, and support the extreme male brain theory. However, we identify a new paradox possibly related to the non-linear effects caused by endocrine feedback mechanisms that must be considered before we can truly understand ASD in the context of the extreme male brain theory.

109.4 MCCRANEY, WT*; ALFARO, ME; UCLA; *tmccraney@g.ucla.edu*
Phylogeny and Diversification of Gobies and their Relatives
Understanding causes for the great unevenness in biodiversity across Earth and the Tree of Life is a major goal of evolutionary biology. The invasion of new habitats such as coral reefs in the ocean or streams on land have been hypothesized as drivers of diversification because they provide ecological opportunity by reducing competition. If habitat transitions provide ecological opportunity, then rates of diversification should be greatest in clades with an evolutionary history of shifts between marine and freshwater habitats. Here we use a time-calibrated, 1006 taxon megaphylogeny of the globally distributed and ecologically diverse Gobiiformes fishes, constructed from a partial matrix of 33 gene sequences to test the hypothesis that habitat shifts drive diversification. We use macroevolutionary modeling of diversification rates and ancestral state reconstruction of habitats to identify lineages in the Gobiiformes radiation that have undergone rapid speciation in marine and freshwater environments. We find strong evidence for diversification rate heterogeneity in Gobiiformes fishes, characterized by a low background rate for non-goby lineages followed by rate increases at the root of the goby clade and several freshwater and coral reef goby lineages. In contrast, we found no variation in diversification rates among the marine cardinalfishes or freshwater sleepers, which supports the hypothesis that transitions between habitats drive diversification.

134.3 MCCUE, M/D*; SALAZAR, G; ALBACH, A; St. Mary's Univ; *mmccue1@stmarytx.edu*
Repeated exposure to food limitation earlier in life enables rats to spare lipid stores during prolonged starvation
The risks of food limitation and ultimately starvation date back to the dawn of heterotrophy; yet, starvation remains a major factor in regulating modern animal populations. Researchers studying starvation over a century ago suggested that animals subjected to sublethal periods of food limitation are somehow more tolerant of subsequent starvation events. This possibility has received little attention over the past decades, yet is highly relevant to modern science for two reasons. First, animals in natural populations are likely to be exposed to bouts of food limitation once or more before they face prolonged starvation during which the risk of mortality becomes imminent. Second, our current approach to studying starvation physiology in the laboratory focuses on nourished animals with no previous exposure to nutritional stress. We examined the relationship between previous exposure to food limitation and potentially adaptive physiological responses to starvation in adult rats and found several significant differences. On two occasions rats were fasted until they lost 20% of their body mass maintained lower body temperatures, and had presumably lower energy requirements when subjected to prolonged starvation than their naïve cohort that never experienced food limitation. These rats that were ‘trained' in starvation also had lower plasma glucose set-points and reduced their reliance on endogenous lipid oxidation. These findings underscore 1) the need for biologists to revisit the classic hypothesis that animals can adapt to starvation using a modern set of research tools and 2) the need to design controlled experiments of starvation physiology that more closely resemble the dynamic nature of food availability.

46.3 MCCULLOCH, KJ*; BRISCOE, AD; University of California, Irvine; *mccullok@uci.edu*

Spectral Tuning in Heliconius Butterflies Following Loss of a Second UV Photoreceptor

For many animals, color vision is essential for survival and reproduction. Butterflies in particular have good color vision and colorful wing patterns that often serve as both predator defense and sexual signals. In the genus *Heliconius*, an opsin gene duplication has resulted in expanded UV color vision in most species, but the *melpomene*/Silvaniform lineage has subsequently lost expression of the UV2 opsin. *Heliconius* species with both UV photoreceptors, or UV2 only, are better able to detect genus-specific wing patterns. With only the UV1 photoreceptor, *melpomene*/Silvaniform visual systems might be similar to non-*Heliconius* outgroups, which do not discriminate *Heliconius* wing patterns well. To further understand how these species might have adapted with only one UV photoreceptor, we investigated mRNA and protein expression in the compound eye of several species, and we measured photoreceptor spectral sensitivities in two representatives, *H. melpomene* and *H. ismenius*. Molecular genetic differences are found in the opsin sequences between the *melpomene* and Silvaniform clades, as well as between the larger *melpomene*/Silvaniform clade and other *Heliconius* species. Photoreceptor sensitivities are shifted when compared to another species with two UV photoreceptors. Differences are found in the numbers and types of ommatidia in the compound eye between species with only UV1 and those with both UV cell subtypes. Taken together, our results suggest loss of UV2 results in spectral tuning in order to better detect salient yellow wing signals.

P2.137 MCDONALD, KL*; GRINDSTAFF, JL; CAMPBELL, P; Grinnell College, Oklahoma State University; *mcdonald2@grinnell.edu*

Candidate Genes for Reproductive Timing in Female Eastern Bluebirds (Sialia sialis)

In an age of global climate change, it is important to understand how organisms respond and adapt to changes in their environment. In temperate birds, the timing of reproduction and other physiological processes is synchronized to the perception of environmental cues, such as ambient temperature. Many species, including eastern bluebirds (*Sialia sialis*), have responded to earlier, warmer springs by advancing the time of egg-laying. This is significant because reproductive timing in birds has major fitness consequences. Genes that modulate seasonal and circadian activities, such as breeding, are called clock genes. Previous studies have shown an association between clock gene polymorphisms and lay date in birds. We tested for associations between first lay date and genotype at four clock genes (*Npas2, Adcyap1, Clock, and Creb1*) in female eastern bluebirds sampled across a six-year period from a single population in Stillwater, Oklahoma. While our preliminary analysis did not find a significant effect of any of the candidate genes on lay date, we cannot rule out the possibility of an effect when populations that experience different temperature regimens are included. This is the first study to investigate the genetic correlates of reproductive timing in eastern bluebirds.

P2.91 MCDONALD, I*; SARWAR, P; SUZUKI, Y; Wellesley College; *imcdonal@wellesley.edu*

The role of Ventral veins lacking in reproduction and embryogenesis in Oncopeltus fasciatus

Hormones play major roles during development and reproduction in multicellular organisms. However, the evolution and development of endocrine glands and hormone biosynthesis are not well understood. The POU factor Ventral veins lacking (Vvl) has recently been shown to play a critical role in endocrine regulation during larval development and endocrine gland development in holometabolous insects. In this study, the role of *vvl* on reproduction and embryogenesis was examined in the hemimetabolous milkweed bug, *Oncopeltus fasciatus*. Silencing the expression of *vvl* using RNA interference (RNAi) in day 1 adult *Oncopeltus* led to reduced egg production. The potential role of *vvl* in adult endocrine regulation during oogenesis was explored using hormone treatments. *In situ* hybridization of *vvl* expression and one of the ecdysteroid biosynthesis genes, *phantom* (*phm*), showed that *vvl* is expressed in the developing prothoracic glands during embryogenesis. A comparison of *phm* expression between embryos of normal wild-type and of *vvl* knockdown females indicates that *vvl* likely regulates the formation of endocrine glands. Given that in mammals, mutations in the vertebrate homolog of Vvl, POU3F2, can lead to hypogonadism, our study suggests that the role of *vvl* in endocrine gland formation and reproduction may be an ancient evolutionarily conserved process.

51.5 MCENTIRE, KD*; MAERZ, JC; Univ. of Georgia, Athens; *mcentire@uga.edu*

How habitat structure and behavior moderate salamander sensitivity to climate

Understanding how climate affects species is a long-standing question in ecology. On an individual level, an organism directly interacts with the microclimate, which is modulated by the vegetative structure. Ultimately, this interaction is governed by an organism's physiology, but behavior can moderate these interactions. We used an individual based modeling (IBM) approach incorporating biophysical models to explore the interactions of vegetative structure and behavior on an organism's physiological interactions with climate using woodland salamanders (genus *Plethodon*) as a model organism. The IBM was simulated using four different scenarios across the same area of Southern Appalachia, where steep rainfall gradients naturally exist. We estimated salamander activity time for a climate only model (baseline), a model including vegetative heterogeneity (presence of midstory canopy plants across half of the area), a model including the ability to climb plants (a potential behavioral strategy to improve foraging ability), and a model including both midstory plants and behavior. The simulations suggested increased potential activity time with the inclusion of vegetative structure and behavior, which moderates the impact of rainfall gradients. This effect was most pronounced for behavioral models and juvenile and hatchling salamanders. The increases in foraging time primarily occurred in the fall. Future climate change models should consider the moderating influences of vegetative structure and behavior on species responses to climate change.

P2.59 MCFADDEN, JG*; HATHAWAY, DA; SIEGWALD, PA; BYRUM, CA; College of Charleston; *byrumc@cofc.edu*

The Sea Urchin Embryo: When and Where are Nuclear Transport Proteins Transcribed in Early Development?

Transport of molecules to and from the nucleus is a critical process controlled, in part, by proteins of the karyopherin-alpha (KAP-α) and karyopherin-beta (KAP-β) families. By regulating entry of transcription factors into the nucleus, karyopherins have the potential to influence cell fate specification and differentiation. To better characterize roles of the karyopherins in these processes, the Byrum lab is developing the sea urchin embryo as a model for investigation of nuclear transport. Traditionally, studies examining these processes utilized yeast or isolated cell lines, but to further explore roles of nuclear transport proteins in developmental events, these processes must be studied in an intact system. The sea urchin embryo offers many advantages for this sort of investigation. In the sea urchin, both transcriptomic and genomic data are available, gene families and molecular networks are simpler than in vertebrates, and cell fate specification/differentiation has been thoroughly investigated. These are just a few of many reasons why the sea urchin would be a strong model. This study is part of an initial effort to better characterize nuclear transport in the sea urchin embryo. Using reverse transcriptase PCR, 16 of the 18 known human KAP-β forms were found to be present in the sea urchin (7 importins, 7 exportins, & 2 transportins). Using wholemount *in situ* hybridization, spatial distribution of several KAP-β forms is described in the developing sea urchin embryo (*Lytechinus variegatus*). The distribution of these forms has been mapped at six distinct stages, from fertilization to the pluteus stage. This study is an important step in developing hypotheses about how these proteins could influence early development and in exploring use of the sea urchin embryo as a model for studying nuclear transport.

117.1 MCGEE, MD*; BORSTEIN, SR; SEEHAUSEN, O; WAINWRIGHT, PC; EAWAG, UT Knoxville, UC Davis; *mcgee.matthew@gmail.com*

Machine learning predicts cichlid feeding kinematics from craniofacial morphology

Machine learning methods, in which an algorithm 'learns' a complex function from data, show great promise in elucidating the relationship between organismal structure and function. However their use in biodiversity research has been limited thus far, in part because many algorithms require the generation of extremely large training sets in order to produce useful models. Here, we utilize several popular supervised machine learning techniques, including support vector machines and random forests, to predict teleost suction feeding kinematics from simple craniofacial landmarks. We assembled a large training dataset of craniofacial photographs and kinematic sequences by filming over five hundred individuals from family Cichlidae, a group of fishes known for their exceptional diversity. We show that these machine learning methods predict kinematics markedly better than simple linear regression techniques, then use the resulting predictive model to reveal kinematic profiles from several 'unfilmable' cichlid communities. We first utilize the method to reveal the feeding kinematics of Victorian cichlid communities prior to the Nile perch-driven mass extinction. We then examine kinematic convergence in deep-dwelling cichlid communities of Lakes Malawi and Tanganyika.

128.1 MCGOWAN, CP*; SCHWANER, MJ; LIN, DL; University of Idaho, Washington State University; *cpmcgowan@uidaho.edu*

Is there a division of labor between proximal and distal muscles of kangaroo rats hopping on an incline?

Within large bipedal hoppers, adaptions of the ankle extensor muscle-tendon units that facilitate economical elastic energy storage also limit their ability to generate mechanical work when moving up slopes. Therefore, a division of labor exists such that the large proximal muscles behave as motors while the distal muscle tendon units behave like springs. However, unlike larger hoppers, kangaroo rats have relatively thick ankle extensor tendons which are unlikely to stretch during normal hopping loads. In a previous study of desert kangaroo rats, we used a joint level analysis of hopping on inclines to show that both proximal and distal joints contribute to providing the mechanical power necessary to raise the animal's center of mass. However, a simple geometrical model based on kinematics and moment arms suggests that the underlying muscle dynamics may not reflect the work being delivered at specific joints. Therefore, in this study we used in-vivo recordings of muscle length change and activity to directly measure how two major extensor muscles are modulated in response to a range of inclines. Sonomicrometry and EMG data were collected from the lateral gastrocnemius (LG) and vastus lateralis (VL) while animals hopped on a motorized treadmill at 0, 10, and 20 degrees incline. Preliminary results show that the VL actively stretches, likely absorbing energy, under all conditions; however, the amount of stretch decreases with increasing incline. The LG undergoes increased active shortening with increasing incline, suggesting that this muscle contributes increased positive mechanical work when hopping up a hill. Therefore, while the knee extensors appear to behave in a similar manner to those of wallabies, the ankle extensors do not, suggesting there is no division of labor.

24.6 MCHENRY, MJ*; NAIR, A; SOTO, A; JOHANSEN, J; LIAO, J; UC Irvine, Univ. of Florida; *mmchenry@uci.edu*

What aspects of performance matter for predator evasion in fish?

It is commonly argued that high locomotor performance enhances an animal's ability to survive predation. However, it is largely unclear what metrics of performance truly matter to survival in predator-prey interactions. We presently studied the strategic implications of the escape response in fish when they encountered fish predators. This was achieved by recording high-speed kinematics of predator-prey interactions and by developing game-theory models of these interaction. We considered these interactions in two very different experimental systems: the suction feeding of the omnivorous adult zebrafish (Danio rerio) as they preyed on zebrafish larvae and the ram feeding of the piscivorous bluefish (Pomatomus saltatrix) as they preyed on mummichog (Fundulus heteroclitus). The escape response was effective for enhancing survival in both experimental systems. However, our game modeling suggests that increasing the speed of an escape and varying its direction have negligible effects on survival. Instead, it is the timing and distance of an escape which offer the greatest impacts on the outcome of a predatory encounter. These results demonstrate how the importance of performance metrics depends on strategy adopted by the predator.

P2.173 MCKECHNIE, MM*; MENDAZONA, RL; TORREZ, S; WALLACE, NE; BALTZLEY, MJ; LATHAM, KL; Western Oregon University, Monmouth; *mmckechnie13@wou.edu*
Using Artificial Selection to Understand Directional Orientation Behavior in Drosophila
Previous studies have shown that the fruit fly *Drosophila melanogaster* can orient using Earth-strength magnetic fields, but the orientation behavior is not consistent across studies. Using a wild-caught population of *Drosophila*, we are attempting to use artificial selection to generate two strains of *Drosophila* that have robust, predictable behaviors which can be used to investigate the underlying mechanisms of magnetoreception. We used a sequential Y-maze to identify both north-seeking and south-seeking flies. After the flies completed the maze, we collected and bred the top 20% of north- and south-seeking flies, then repeated the protocol for 15 generations. As a positive control, we also performed a similar set of selection experiments to breed a population of positive phototaxic and negative phototaxic flies. We have now begun testing whether the generation 15 flies have developed directional preferences. We have so far completed 4 replicates with each line of *Drosophila*. As of May, 2016, our preliminary results ($n = 4$) indicate that *Drosophila* show positive phototaxis and that our light-selected flies have a significantly stronger preference for light than our dark-selected flies ($p < 0.05$). Our results also indicate that our north-selected and south-selected *Drosophila* do not have different directional preferences based on Earth-strength magnetic fields ($p = 0.26$). We will present our updated results and ultimately plan to continue our experiments through 10 replicates with each line of flies. If we find that we have in fact created two lines of *Drosophila* with different magnetic field directional preferences, we will begin experiments to identify the genetic basis of the directional preferences. If we have not created flies with distinct directional preferences, we plan to continue our selection experiments for another 15 generations.

35.3 MCKEE, A*; MCHENRY, MJ; University of California, Irvine; *aamckee@uci.edu*
Growth changes the escape response to visual looming stimuli in zebrafish
Fish rely on vision to detect and evade approaching predators with a fast-start escape response. It is unclear how this ability changes over the course of a fish's growth, as the visual system transforms dramatically from larval to adult stages. We compared the escape kinematics of zebrafish in response to a projected looming stimulus (an expanding black circle). This was achieved using an automated system that performed experiments on individual larval, juvenile and adult zebrafish (*Danio rerio*). We found that fish of different ages vary in their spontaneous swimming and response to a looming stimulus, as measured by changes in heading and speed. In particular, juvenile fish showed the greatest rate of spontaneous swimming and a relatively high responsiveness to a looming stimulus. These results show that escape responses are not static in fish, but change through growth. This perspective sheds new light on previous studies on escape responses in fish.

P1.97 MCKENNA, KZ*; NIJHOUT, HF; Duke University; *kzm@duke.edu*
Allometry and Reaction Norms: Wing-Body Scaling in Manduca sexta
Allometry, the proportional growth of the body and body parts, gives rise to the characteristic forms of species. Most studies concerned with allometry have focused on its role as a developmental constraint, neglecting the possibility that alternative scaling relationships emerge from differing growth conditions. The study of reaction norms, the effect of environmental factors on growth, size and shape, has neglected allometry for this same reason. A few studies in insects have surveyed the effect of different growth conditions on allometry, and they have demonstrated that scaling relationships are greatly influenced by environmental factors such as nutrition, population density, and temperature. We argue that allometric scaling relationships can be viewed as reaction norms, whereby the relative size of body parts is influenced by both the growth of the body and the environment. We show how environmental factors influence the proportional growth of wings in the tobacco hornworm *Manduca sexta*. We demonstrate that 1) the growth of the body and the wings are influenced by external developmental conditions, 2) the slope of the population wing-body scaling relationship changes when larvae are reared under different growth conditions such as temperature and nutrition, and 3) these differences are caused by changes in the relative duration of the growth of the wings. We will use a new allometry equation to deduce and predict how different growth conditions influence wing-body scaling.

S5.4 MCKENZIE, VJ*; SONG, SJ; AMATO, KR; DELSUC, F; METCALF, JL; SANDERS, JG; KNIGHT, R; University of Colorado, Northwestern University, Université Montpellier, Colorado State University, University of California San Diego; *valerie.mckenzie@colorado.edu*
The effects of captivity on the vertebrate microbiome
Recent studies are increasingly noting the effect of captivity or the built environment on the microbiome of humans and other animals. As symbiotic microbes are essential to many aspects of biological functioning (e.g., digestive and immune functions), it is important to understand how lifestyle differences can impact the microbiome, and consequently the health of hosts. Animals living in captivity experience a range of changes that may influence the microbiome, such as diet changes, treatments, and reduced contact with variable environmental substrates that act as sources of bacterial diversity. Thus far, initial results from previous studies point to a pattern of decreased bacterial diversity in captive animals, but these studies are relatively limited in the scope of species that have been examined. We endeavor to use a novel dataset that comprises paired wild and captive samples from more than 25 species across a range of vertebrates to investigate generalizable patterns of the effect of captivity on the microbiome. We discuss whether a pattern of decreased bacterial diversity in captivity is observed universally, and examine specific bacterial groups that appear to respond consistently. We also examine whether host traits, such as diet type, body size, etc. influence the effect of captivity on the microbiome, and discuss the broad functions that are involved with the bacterial groups that respond to captivity. Overall, the patterns that we observe will inform a range of disciplines from medical and veterinary practice to captive breeding efforts for biological conservation.

110.1 MCMAHON, JD*; LASHLEY, MA; BARTON, BT; Mississippi State University ; *jdm1346@msstate.edu*

Are GUDs Duds? Predation Risk Alters Nutrient Preferences in Giving-Up Density Experiments

Giving-up density (GUD) experiments are a common technique used to evaluate perceived predation risk. These experiments use food consumption as a proxy for predation risk, assuming greater amounts of food will be left unconsumed as risk perception increases. Implicit to this experimental design is the assumption that the perceived value of a food item does not change across levels of predation risk, so that differences in consumption indicate differences in predation risk. However, recent studies have shown that in some species, including grasshoppers, predation risk elevates metabolic rate and causes them to shift dietary preferences toward carbohydrate-rich (C-rich) foods and away from protein-rich (N-rich) foods. This suggests that the interpretation of GUD experiments may be confounded by perceived food values that change across levels of predation risk. We conducted a series of lab experiments to test the hypothesis that carbohydrates and proteins change in relative importance to prey when facing predation risk, and consequently the GUD framework may over- or under-estimate predation risk depending on the nutrient value of the food used. We presented grasshoppers with two artificial diets (C-rich or N-rich foods) in choice or no-choice trials and found that the presence of spiders reduced consumption of the N-rich food and increased consumption of the C-rich food. Next we conducted a GUD experiment using enclosures stocked with a known number of spiders (0-5) to see how GUD differed between C-rich and N-rich foods. As predicted, GUD of N-rich food increased with spider density, but was invariant when using C-rich food. These results suggest that GUD experiments using a C-rich food may underestimate predation risk, whereas using a N-rich food may overestimate predation risk.

61.1 MCMENAMIN, SK*; CARTER, C; COOPER, J; NAZAIRE, C; KHALID, A; University of Massachusetts, Lowell, Washington State University, Tri Cities; *skmcmena@gmail.com*

Thyroid Hormone Integrates Craniofacial Development and Feeding Kinematics in Zebrafish

Thyroid hormone (TH) is critically important to numerous aspects of vertebrate development, and can affect coordinated suites of traits. The hormone affects ossification and craniofacial morphogenesis, but the specific sensitivities of different craniofacial elements, and the integration with functional feeding behavior remained poorly understood. We show that in zebrafish, normal levels of TH are required for proper craniofacial development, and for normal kinematic integration of adult feeding behavior. Hypothyroidism results in incomplete ossification of numerous bones and altered craniofacial proportions. We show that TH is required for properly integrated suction feeding behavior, and that a lack of TH disrupts feeding kinematics in several respects, including changes to jaw protrusion, cranial elevation and hyoid depression. Moreover, we find that the hormone coordinates the onset of adult feeding behavior, and that the feeding kinematics of hypothyroid adults resemble those of larvae in certain aspects. Given the coordinated changes induced by modulating TH, evolutionary changes in TH production and metabolism are hypothesized to play an important role in craniofacial adaptation and diversification. To place the craniofacial skeletogenesis and feeding behaviors influenced by TH into a broader phylogenetic context, we examined the feeding kinematics of seven other Danionin species, including the paedomorphic genus Danionella. We show that disrupted TH metabolism in zebrafish causes some aspects of craniofacial morphometrics and feeding kinematics to more closely resemble those of other species, suggesting that changes in TH may indeed play a role in craniofacial diversification.

P1.22 MCPHERSON, DR; SUNY Geneseo, Geneseo, NY; *mcpherso@geneseo.edu*

Peripheral Projections of Serotonergic Neurons in the Nudibranch Gastropod Melibe leonina

Serotonin is involved in many aspects of the behavior of gastropod molluscs, and the cell bodies of neurons that release serotonin have been anatomically mapped in the brains of many species. Most of the peripheral nerves of gastropods contain serotonergic axons, as do the pedal commissures, but the source neurons for those axons are known in only a few examples. The task of the current project is to backfill peripheral-projecting neurons with biocytin and to identify the serotonergic neurons within the backfilled population by whole-mount indirect immunocytochemistry using antibodies to serotonin. The experiments were carried out using isolated brains of the hooded nudibranch *Melibe leonina*, and backfills were made on the major cerebral, pedal, and tentacular nerves, plus the pedal commissures, leaving the other nerves for future studies. The results will be compared with what is known in other opisthobranch molluscs.

P3.55 MCQUEEN, EW*; GLASSFORD, WJ; REBEIZ, M; Univ. of Pittsburgh, Columbia Univ.; *ewo3@pitt.edu*

Pleiotropic Genetic Architecture Accompanies Concomitant Origin of a Pair of Novel Male and Female Genital Structures

While the evolutionary origins of novel morphologies is a fundamental question in evolutionary developmental biology, perhaps a greater challenge is to elucidate how novel co-evolving structures arise. Animal genitalia present a particularly interesting case for studying this problem, due to the rapidity with which these structures change form and their inherent requirement for interacting male and female morphologies. Although past research has generally focused on male anatomies, recent advances have revealed rapidly evolving complex structures in females as well. However, the degree to which these co-evolving genital structures are genetically independent is currently unknown. In the *Drosophila melanogaster* subgroup, males possess a novel genital outgrowth called the posterior lobe, which is used to clasp females during mating. It was recently discovered that females of this subgroup have a novel feature of their ovipositor that appears to interact with the posterior lobe. A gene network required for posterior lobe formation was found to be co-opted from a larval structure during the origin of the male structure. Surprisingly, we discovered that genes and enhancer regions from that network that contribute to the posterior lobe's development are also involved in the patterning and formation of the corresponding female structure. These data suggest that the necessarily-shared genetic history between the two structures could in part explain the simultaneous origin of two seemingly morphologically autonomous sexual characters.

P3.43 MCQUILLAN, MA*; ROTH, TC; RICE, AM; Lehigh University, Bethlehem, PA, Franklin and Marshall College, Lancaster, PA; *mam612@lehigh.edu*

Testing the Role of Cognitive Ability as a Reproductive Isolating Barrier

Identifying the barriers that prevent gene flow between closely related species is a fundamental goal in evolutionary biology. A potential reproductive isolating barrier that has not yet been tested is cognitive ability. Cognitive traits, such as spatial memory and learning ability, are important for fitness in food-caching birds, where accurate cache retrieval is crucial for survival in harsh environmental conditions. Here, we compare the spatial memory and learning ability between two North American species of food-caching songbirds and their naturally occurring hybrids (Black-capped chickadees, Carolina chickadees, and hybrid chickadees). We hypothesize that hybrid chickadees will be cognitively deficient relative to pure species individuals. To test this hypothesis, we subjected wild-caught black-capped (*Poecile atricapillus*), Carolina (*P. carolinensis*), and hybrid chickadees to a set of behavioral experiments designed to test cognitive ability in an outdoor aviary setting. Our preliminary results suggest that hybrid chickadees perform worse on spatial memory tasks and novel problem-solving tests than pure species individuals. These experiments suggest that impaired cognition may function as a source of selection against hybrids in nature, and may contribute to maintaining reproductive isolation between chickadee species.

134.4 MCTERNAN, MR*; ANDERSON, RA; POWERS, SD; Western Washington Univ., Bellingham, WA, George Fox Univ., Newberg, OR; *mcternm@wwu.edu*

Resting metabolism comparisons among populations of a subspecies of lizard differing in climate and vegetation types

The geographic range of the Western Fence Lizard *Sceloporus occidentalis* covers 15° of latitude, nearly 1500 meters in elevation, and occupies a broad range of biomes. We asked whether physiological adaptation to local conditions are necessary for success across such a large geographic range. On a smaller geographic scale, a single subspecies of *S. occidentalis* comprises populations from three distinctly different climate zones in the state of Washington: pine-oak woodland in the inland south, pine-fir forest in the North Cascades, and forest edge along the Salish Sea coast. We hypothesized that lizards from the cool coastal locale would show elevated metabolic rates relative to the other sites to accommodate the cooler daily temperatures and shorter activity season. We compared the temperature-dependent resting metabolism at body temperatures of 20, 28 and 36°C among the three populations, tentatively supporting our hypothesis.

66.5 MEACHEN, JA*; BITTERMAN, KM; THOMPSON, ME; BRANNICK, AL; Des Moines University, Idaho Museum of Natural History, University of Washington; *julie.meachen@dmu.edu*

Identity of Ice Age Idaho wolves

Beringian wolves are an extinct group of Pleistocene-aged wolves from Alaska that specialized in hunting ice age megafauna. They were morphologically and genetically distinct from grey wolf (*Canis lupus*) and morphologically distinct from dire wolf (*Canis dirus*). The recent discovery of Beringian wolves at the late Pleistocene fossil site of Natural Trap Cave (NTC) in northern Wyoming marks the first record of this type of wolf in the contiguous U.S. Their migration followed an ice-free corridor from Alaska to Wyoming before the last glacial maximum, begging the question: Did Beringian wolves make it elsewhere in the contiguous U.S.? We collected 2D geometric morphometric data from photos of wolf mandibles from Alaska and WY-NTC (Beringian wolves), Rancho La Brea (RLB) in southern California (dire wolves), Idaho (purported dire wolves), and extant grey wolves from northwestern North America. We analyzed these images using 16 landmarks in tpsDig2. PCA and CVA analyses were run in PCAgen and CVAgen programs, and ANOVA was run on the PC scores to compare groups. Results show that the Idaho wolves are indistinguishable from NTC Beringian wolves and RLB dire wolves on PC1 and that they group with RLB dire wolves on PC2. In size, Idaho wolves group solidly with NTC Beringian wolves, and are significantly smaller than dire wolves. These findings suggest that the Idaho wolves are not the same species as is found at Rancho La Brea and that there was some hybridization between dire wolves and Beringian wolves in southern Idaho. Hybridization between modern canids is a common occurrence and our results would suggest that canid hybridization also occurred in the Pleistocene. The next step is to examine ancient DNA to assess whether the morphology concurs with the genetics of these ancient wolves.

85.5 MEAD, M.S.*; HOWEY, C.A.F.; LANGKILDE, T.; The Pennsylvania State University; *msm5545@psu.edu*

Impacts of pH and UV-B on Stress and Developmental Rates of Wood Frog Lithobates sylvaticus Tadpoles: Implications with Regard to Prescribed Fire.

Prescribed burning is a forest management technique that may affect pH and UV-B levels within vernal pools. UV-B exposure can cause morphological and behavioral abnormalities and can delay larval growth and development in amphibians. Low pH levels (e.g., 4.5) may also decrease growth rate and result in a longer larval period. The objective of this study was to determine how variations in pH and UV-B exposure interact to impact developmental rates and stress levels. Wood frog tadpoles were exposed to 3 different pH treatments (4.5, 5.5, and 6.5) and 3 different UV-B exposure treatments (1, 3, and 5 hrs) in a controlled laboratory setting. Our study design allowed us to test the effects of these treatments and interactions between treatments. Throughout the course of this experiment we measured developmental rates, changes in body condition, survival, and corticosterone levels (proxy for stress). Given that prescribed fire may influence canopy cover and water pH of vernal pools, our results suggest that prescribed fire may also influence tadpole developmental rates and stress levels. Future forest management practices may need to consider how they affect vernal pools in accordance with these results.

P1.164 MEDINA-BAEZ, OA*; NOVARRO, AJ; University of Puerto Rico, Mayagüez, University of Maryland, College Park; *osmary.medina@upr.edu*

Which species is better equipped for climate change? Thermal limits in two widely distributed salamanders

With rising temperatures due to climate change, we expect shifts in the geographic range of many species. Among the species most affected by these dramatic changes in temperatures are the lungless salamanders (family Plethodontidae). Because plethodontids are ectotherms, have permeable skin, are lungless and therefore need cold and wet temperatures to receive oxygen, we expect rising temperatures to cause a reduction in suitable habitat. Individuals that can tolerate a broader range of temperatures should be more successful when experiencing drastic changes in climate. To better understand species' response to climate change, we determined thermal limits in two species with expansive, but varying geographic ranges: the Eastern red-backed salamander (*Plethodon cinereus*), and the northern slimy salamander (*Plethodon glutinosus*). Additionally, we measured CT limits for both species at high and low elevations to account for geographic variation in thermal physiology. After acclimating all individuals to a similar temperature for 7-10 days, we measured critical thermal minimum (CTmin), critical thermal maximum (CTmax), and calculated thermal breadth (CTmax - CTmin). We found that *P. glutinosus* has a broader thermal breadth than *P. cinereus*, and that CTmin and CTmax generally decreased with elevation. CTmax was higher for *P. glutinosus*, whereas CTmin depends on species and elevation. Based only on their CT limits, we expect *P. glutinosus* to tolerate a wider range of temperatures and, therefore, be more resilient to climate change. Quantifying species' thermal limits will enhance our predictions of geographic range shifts in response to climate change.

144.4 MEDINA-GARCÍA, A*; WRIGHT, T F; New Mexico State University; *amedinag@nmsu.edu*

Exploring Female Mate Choice for Cognitive Abilities in Budgerigars

Cognitive processes play a major role in a multitude of behaviors, including foraging behavior, parental care, and predator avoidance. Despite the impacts of cognition on individual fitness, the action of sexual selection on cognitive traits remains poorly understood. In socially monogamous species in which males contribute heavily to the raising of offspring, females obtain direct benefits through male parental care. Male cognitive skills will directly impact offspring survival and quality by the ability to obtain resources and coordinate reproductive efforts with their mate. Thus, it is expected that females might select males that show high cognitive performance. We tested the hypothesis that females prefer males with higher cognitive abilities in a small parrot, the budgerigar (*Melopsittacus undulatus*). 30 male budgerigars were tested on four cognitive tasks: problem solving, spatial memory, detour reaching, and seed discrimination. We also measured four personality traits (neophobia, exploration, sociability, and aggressiveness) and male body size. Male mating success was determined with a free-pairing experiment: Five mixed groups of six randomly selected males and three females each were formed to test female mate choice. Males exhibited substantial individual variation in performance in all cognitive tasks. We found little evidence that females choose social mates based on their cognitive performance, personality traits, or body size. However, male cognitive abilities may still play a role in cryptic mate choice (i.e. extra-pair copulations). Alternatively, female budgerigars may use other traits such as vocal learning ability or plumage to select their social mates.

123.2 MEHTA, RS*; MORGIA, JM; SALLADAY, K; JACQUEMETTON, CP; BUSBY, WP; WARD, AB; MEHTA, Rita; Univ. of California, Santa Cruz, Adelphi University; *rmehta2@ucsc.edu*

The Effects of Substrate on Terrestrial Locomotion in the Snowflake moray, Echidna nebulosa

Despite the fact that fishes are well adapted for an aquatic lifestyle, many members of disparate teleost lineages can traverse the terrestrial environment. Rather than having robust fins that act as limbs, many amphibious fish have evolved towards the opposite trend: pectoral and pelvic fin reduction or the absence of these fins and extreme elongation of the body or tail. Highly elongate fishes tend to move by axial undulation-lateral movement of the body in which sinusoidal waves are produced, similar to snakes. Highly elongate fish that are capable of terrestrial excursions tend to live at the interface of mud flats, sand, and the rocky intertidal. Despite the fact that the elongate body plan has evolved multiple times in bony fishes, terrestrial locomotion has been studied in only two taxa: the American eel, *Anguilla rostrata*, and the ropefish, *Erpetoichthys calabricus*. In this study, we examine the ability of the snowflake moray, *Echidna nebulosa*, to traverse a pebble substrate. The pebble substrate had four combinations of treatments: wet, dry, unanchored and anchored. Our preliminary data suggests that substrate type has an effect on the continuity of locomotion. We also discovered that substrate type had an effect on the locomotor behavior employed. While lateral undulation was commonly observed, we also observed rectilinear locomotion and individuals gripping onto the substrate using lateral expansion of their bodies. This suggests that the snowflake moray may exhibit a diversity of locomotor behaviors similar to terrestrial snakes.

1.2 MEISEL, RP; University of Houston; *rpmeisel@uh.edu*

The Evolution of Sex Determination in House Fly

Sex determination is an essential developmental pathway in many animals, yet genes required for sex determination are poorly conserved even between closely related species. Multiple hypotheses have been presented to explain the paradoxically fast evolution of sex determination pathways, but explicit tests of these hypotheses are lacking. The house fly is an ideal model system for testing these hypotheses because multiple different sex determining loci segregate in natural populations, and the distribution of these variants is associated with geographic latitude and some environmental factors. I will present results of experiments using house flies that test hypotheses that could explain the fast evolution of sex determination pathways and identify developmental consequences of evolutionary changes in sex determination. Using population genetic analyses and functional genomic experiments, I have determined that inter-sexual conflict or sex-specific selection pressures are important for the maintenance of polygenic sex determination in house fly. In addition, I show that temperature is an important ecological factor that affects the phenotypes of different house fly sex determining genotypes. These results demonstrate that sex-specific selection pressures are ecologically dependent, and they suggest that a complex interplay of genotype and environment affect the evolution of sex determination.

108.3 MEKDARA, PJ*; COUGHLIN, LL; SCHWALBE, MAB; TYTELL, ED; Tufts University; *prasongmekdara@gmail.com*
Learning to School Again: How Ablation and Regeneration of the Lateral Line System Alters Schooling Behavior in Giant Danios
Fish use their lateral line system to maintain position and speed within a school. They also use vision for schooling because fish without a functional lateral line system can still school, as long as they can see. However, this conclusion was based on an experiment in which only the posterior lateral line system was disabled, leaving the anterior lateral line system intact. In this study, we examined schooling behavior in fish immediately after their lateral line systems were completely ablated and at weekly intervals while this system regenerated. We filmed groups of giant danios (*Devario aequipinnatus*, 5 fish/group) with two high-speed cameras and reconstructed the 3D positions of each fish within a group. One fish in the school was treated with gentamycin, an aminoglycoside antibiotic that is toxic to hair cells located in neuromasts. Fluorescent staining of the lateral line system showed complete ablation of both the canal and superficial neuromasts from the antibiotic treatment, and full regeneration of the hair cells after one week. As the treated fish swam within the school, we quantified the overall structure of the school by calculating the nearest neighbor distance, bearing, elevation, and angular velocity correlations between each pair of nearest neighboring fish. We found that the treated fish were able to maintain a normal position within the school immediately after the lateral line ablation, but these fish could not school normally one week after treatment while the hair cells in the neuromasts were regenerating. By eight weeks post-treatment, the treated fish could again school normally. These results suggest that fish may need more time than previously thought to relearn how to process signals from newly regenerated hair cells of the lateral line system.

146.1 MENARD, S/S*; WATSON, G/M; University of Louisiana at Lafayette; *ssm2041@louisiana.edu*
Sea anemone hair bundles are resilient to multiple types of trauma.
Tentacles of sea anemones are covered with hair bundle mechanoreceptors that are employed to detect swimming movements of prey. Previously, sea anemones were exposed to calcium-depleted seawater in order to traumatize the hair bundles. This trauma disrupts linkages interconnecting stereocilia of the hair bundle. The linkages are necessary to maintain structural integrity of the hair bundle. This type of damage mimics that caused by large mechanical forces presumably experienced by the animal in nature. Due to the rapid recovery of anemone hair bundles following this type of trauma, however, it is thought that exposure to calcium-depleted seawater does not cause hair cell death. Is this resiliency of anemone hair bundles limited to restoring linkages? In the current study, we employed Cytochalasin D (CD), a fungal toxin that prevents actin polymerization, to damage the core of polymerized actin that forms the cytoskeleton within the stereocilia of anemone hair bundles. We determined the extent of damage caused to the hair bundles by evaluating hair bundle abundance, morphology, function, and relative F-actin content after CD trauma. We found that hair bundle abundance and function decrease with CD treatment, while morphology and relative F-actin content remain unchanged relative to controls. Hair bundle abundance returns to control levels within three hours. Although CD changes some aspects of vibration sensitivity in sea anemones, a base level of function remains. Taken together, these data confirm the resiliency of anemone hair cells.

P2.172 MENDAZONA, RL*; WALLACE, NE; MCKECHNIE, MM; TORREZ, S; BALTZLEY, MJ; LATHAM, KL; Western Oregon University, Monmouth; *rmendazona12@wou.edu*
Determining Whether Drosophila Have an Innate Directional Preference Based on the Ambient Magnetic Field of the Earth
Over 150 different species of animals have been shown to use the Earth's magnetic field for orientation and navigation; however, the basic mechanisms underlying magnetoreception are not yet well understood. The fruit fly *Drosophila* melanogaster is an attractive organism for studying magnetoreception because it is a model organism for understanding the genetic basis of behavior and could therefore lead to insights regarding the cellular mechanisms of magnetoreception. Several studies suggest that *Drosophila* can detect magnetic fields, but the behavioral responses of fruit flies to magnetic fields vary from study to study. In an effort to confirm whether or not *Drosophila* have an innate directional preference, we designed a sequential Y-maze so that in each experimental trial *Drosophila* make multiple directional choices based on the Earth's ambient magnetic field. The directional preferences of male and female flies were analyzed separately because one previously published study found that male flies orient to magnetic fields, but female flies do not. We found that the orientation of neither male nor female flies was different from a random distribution ($p > 0.9$). Our results indicate that adult *Drosophila* do not have an innate magnetic directional preference; however, our results do not eliminate the possibility that *Drosophila* can detect magnetic fields. The absence of a strong innate directional preference in *Drosophila* may be the primary reason that significant progress in identifying a magnetoreceptor in *Drosophila* has not been made. We have begun a long-term selective breeding experiment in an effort to develop a line of strongly magnetotaxic *Drosophila* with a robust, predictable behavior that can be used to tease apart the underlying mechanisms of magnetoreception.

48.8 MENDELSON, JR*; LI, TD; RIEDO, E; GOLDMAN, DI; Zoo Atlanta, CUNY Advanced Science Research Center, Georgia Institute of Technology; *jmendelson@zooatlanta.org*
Functional Significance of the Derived Morphology of Ventral-Scale Nanostructure in the Sidewinder
Ventral surfaces of snakes typically contact the substrate during locomotion, with lifting being an important component especially in sidewinding. Studies of the functional and physical properties of ventral scales of many snakes have found no clear ecological or phylogenetic patterns to contextualize observed variation in surface nanostructures. We used Atomic Force Microscopy to study the 3-D nanostructure of the ventral scales of the Sidewinder, a species known for distinctive lateral and lifting locomotion and exceptional abilities on granular substrates. Examination of a diversity of related pitviper species documented a conserved morphology of regularly ordered, uplifted, sharply pointed, posteriorly protruding nanostructures with typical dimensions of 3 µm x 0.5 µm x 0.15 µm (length, width, height); small epidermal pits with typical diameter of 100 nm, but of unknown function, are present as has been found in other snakes. This morphology is generally representative of the ventral nanostructure anisotropy seen across virtually all snakes, clearly associated with the plesiomorphic mode of anteriorly directed locomotion. Our outgroup comparisons identified the distinctive morphology of Sidewinders as a derived condition, with a flat surface and modified (1 µm x 1 µm x 0.05 µm), blunted, posteriorly oriented vestiges of the rearward projections of other pitvipers; epidermal pores were present, but larger (300 nm diameter) than any snake yet examined. This unique, phylogenetically derived 3-D nanostructure with low directionality could provide isotropic friction for the derived pattern of locomotion of Sidewinders involving lateral forces, abrupt directional reversals, and lifting.

12.2 MENDELSON, L*; TECHET, AH; MIT; *leahm@mit.edu*
Spatially constrained acceleration in jumping archer fish, Toxotes microlepis
Archer fish (*Toxotes microlepis*), best known for their ability to spit jets of water at aerial prey, will also jump multiple body lengths out of the water for prey capture, especially in competitive foraging scenarios where kleptoparasitism is prevalent. Aiming prior to jumping or spitting occurs from a stationary position with the snout directly below the free surface. Rapid acceleration to a ballistic velocity sufficient for reaching the prey height occurs with only a body length to travel before the fish leaves the water completely and experiences a thousandfold drop in force producing ability. Simultaneous high-speed, three-dimensional measurements of fin kinematics and aerial body trajectories highlight multiple strategies for such spatially constrained acceleration. The fish performs an S-type acceleration maneuver, followed by additional caudal fin strokes with the motion envelope more confined to the submerged portion of the body. The pectoral and pelvic fins rapidly extend fins at jump onset, altering the added mass forces acting on the fish. Volumetric synthetic aperture particle image velocimetry (SAPIV) is used to provide time-resolved measurements of fluid wake development during a jump, including simultaneous quantification of contributions made by the pectoral, anal, and caudal fins to the wake kinetic energy. 3D fluid flow measurements also enable assessment of propulsive efficiency, which is crucial to understanding jumping's role as an energetically viable hunting strategy for the fish.

P3.218 MENDOZA, E*; AZIZI, E; MOEN, DS; Oklahoma State University, University of California, Irvine; *meel@ostatemail.okstate.edu*
Anuran Jumping Performance as a Consequence of Changes in Aponeurosis Stiffness
Anuran jumping is a single discrete movement that requires substantial power. Previous studies have shown that whole-organism muscle-mass specific power in frog jumping differs substantially between three diverse species. However, these differences in whole organism muscle-mass specific power are not explained by the organisms' maximum muscle power output. Power output during *in vitro* muscle stimulation for all three species falls within the muscle physiological limit of approximately 300 W/kg. The disparity between whole-organism power and maximal muscle power output has been attributed to the utilization of elastic mechanisms to amplify power output, yet the general importance of these mechanisms in explaining species differences is unclear. We test the hypothesis that variation in the mechanical properties of tendons underlies interspecific variation in whole-organism power output and explains the disparity between muscle performance and whole-organism performance. Using 18 Oklahoman frog species that cover both advanced (Neobatrachia) and basal (Archaeobatrachia) frogs, we first recorded frogs jumping with high-speed video to calculate muscle-mass specific power output and test for differences across species. Next, we used materials testing to determine whether such differences are due to differences in the stiffness and elastic modulus of the aponeurosis surrounding the *plantaris longus* muscle. Our preliminary results highlight variation in jumping abilities between different species of frogs. Additionally, disparities in elastic modulus between a subset of families suggest that changes in aponeurosis material properties may be in part responsible for differences in jumping performance. By investigating the material properties of the aponeurosis, we aim to understand how structural changes drive variation in diverse locomotor strategies of frogs.

P3.61 MENSINGER, AF*; ROGERS, LJ; VAN WERT, JC; University of Minnesota Duluth, University of California Berkeley; *amensing@d.umn.edu*
Chronically Implanted Micromanipulator for Recording Neural Activity from Free-swimming Fish.
Chronically implanted headstage/electrode devices allow monitoring neural activity from free moving terrestrial animals. However, these devices have not been available for fish which resulted in chronically implanted electrodes being glued into place and unable to be repositioned which limited the experiment to the origin implant site. In this study, an implantable two axis micromanipulator was fabricated from a 3 dimensional printer to record neural activity from toadfish. The manipulator consists of a platform, pilot, electrode chamber and screw. The manipulator measured approximately 25 x 20 x 30 mm (l x w x h) and weighed 5.28 grams. Microwire electrodes were inserted through the manipulator to record from the anterior lateral line nerve of the toadfish. The manipulator and resulting craniotomy was sealed with cyanoacrylate glue and the skin sutured around the turn screw to provide a water tight seal. Following implant, high fidelity signals were recorded from multiple afferent fibers in the anterior lateral line of the toadfish. Additional fibers could be recorded from by manually turning the manipulator drive.

P2.57 MENZEL, K/G*; RENN, S/CP; RITZ, A; Reed College; *menzelk@reed.edu*
Analysis of copy number variation across African cichlid genomes
Structural variation has been shown to be a major source of genomic polymorphism and evolutionary novelty, including adaptive evolution. The African cichlids, known as one of the most explosive examples of an adaptive radiation, offer an excellent model with which to study the genetic basis of adaptation and diversification in Vertebrates. The recent genome sequencing for 5 species of African cichlids provided the key genomic resources to develop an array based Comparative Genomic Hybridization (aCGH) to analyze the structural variation at the whole genome level across African cichlids lineages. We use a novel "genecentric" high-density multi-species microarray platform with probes space at intervals of approximately 6Kb. This should allow detection of structural variation of 30-60Kb. Here, we used this high-density array platform to analyze genome level CNV among the 5 previously sequenced cichlid species, representing three major evolutionary lineages of African Cichlids. To estimate the level of CNV polymorphism, individuals from natural populations of each species have been analyzed and compared to the populations from the sequenced individuals. We also quantify copy number variation across a broad phylogenetic range of 50 African cichlids. We infer copy number status for each of the species as well as shared status among related clades. We then map the copy number status to the current mitochondrial phylogeny for the 50 species in order to determine the evolutionary history of copy number variation among cichlids and its relationship to adaptive radiation.

P3.77.5 MERLINO, LJ*; SHINKLE, CJD; SILVA, J; CODDINGTON, EJ; Willamette University, Salem, Oregon; *ljmerlino@willamette.edu*

Identifying the role of TRPV1 in cannabinoid mediated suppression of vasotocin endocytosis in the medullary reticular formation of Taricha granulosa

An animal's ability to perform context-specific behaviors in response to immediate threats is an essential skill for survival and reproduction, yet little is understood about the non-genomic mechanisms involved in acute contexts. In rough-skinned newts (*Taricha granulosa*), the stress hormone corticosterone suppresses clasping, a context-specific sex behavior, via cannabinoid (CB) signaling. Prior research suggests that endocytosis of vasotocin, the analogue to mammalian vasopressin, is required for clasping and is blocked by elevated corticosterone. This research project aims to identify if, and to what extent, transient receptor potential vanilloid 1 (TRPV1) is involved in CB-mediated suppression of vasotocin. N-arachidonoyl-dopamine (NADA) is an endogenous agonist of TRPV1 and CB1 receptors, which are both expressed in the medullary reticular formation of *Taricha*. Given its dual role as an endocannabinoid and endovaniloid, it is predicted that NADA (2.2ng/µl) administered via intracerebroventricular injection will, like other endocannabinoids, suppress vasotocin endocytosis. We examine whether pre-treatment with the TRPV1 antagonist SB366791 (0.29ng/µl) and/or the CB1 antagonist AM281 (50ng/µl) will inhibit NADA (2.2ng/µl) suppression of vasotocin endocytosis, and if so to what extent. We have used quantitative confocal imaging to examine this question, focusing on the rostromedial reticular formation in the medulla oblongata as it is a primary mediator of behavioral switching and initiation of locomotion in all tetrapods.

62.5 MERRILL, L*; CHIAVACCI, S; SANTYMIRE, R; HAUSSMANN, M; PAITZ, R; BARGER, A; BENSON, TJ; University of Illinois, Urbana-Champaign, Lincoln Park Zoo, Bucknell University, Illinois State University; *loren21@illinois.edu*

Parental investment, phenotypic correlations, and landscape: understanding the role of habitat in shaping wild bird phenotypes

Early life conditions are important for shaping the adult phenotype of many organisms. For wild birds, features of the landscape can impact nestling development indirectly via parental effects, and directly via food quality, predation and disease risk. In this study we investigated the relationships between landscape features and parental investment and nestling condition for five shrubland birds breeding across a gradient of developed land and shrubland. Our focal bird species were American robin, northern cardinal, field sparrow, brown thrasher, and grey catbird. We found that parental investment and the associations among morphometric traits varied with changes in land cover, providing evidence for the importance of continuous variation in nest-site habitat features on the development of wild birds.

20.6 MERRITT, JR*; MAYS, SG; ORTLUND, EA; MANEY, DL; Emory University, Emory University, School of Medicine; *jrmerri@emory.edu*

An estrogen receptor alpha polymorphism may mediate behavioral polymorphism in the white-throated sparrow

The white-throated sparrow is powerful model in behavioral neuroendocrinology because it exhibits a chromosomal inversion ($ZAL2^m$) that segregates with crown plumage and steroid-dependent behavior. Birds of the white-striped (WS) morph are heterozygous for the $ZAL2^m$ rearrangement and exhibit higher levels of vocal aggression than birds of the tan-striped (TS) morph, which are ZAL2 homozygotes. Recombination suppression between ZAL2 and $ZAL2^m$ has resulted in the divergence of captured genes, including ESR1, which encodes estrogen receptor alpha (ERα). ERα expression in the brain depends strongly on genotype and predicts territorial aggression. Here, we used complementary in vitro and in vivo approaches to test a model in which regulatory variation in ESR1 contributes to variation in aggression. First, we established that regulatory regions upstream of ESR1 contain fixed SNPs that occur in putative binding sites for transcription factors and CpG sites. Using a reporter assay, we found that the level of transcription depended on haplotype. Our results suggest that sequence divergence may explain the known morph differences in ERα expression in the brain. Next, we performed a behavioral study in which we manipulated estradiol (E2) levels. We reasoned that if the morph difference in ERα expression contributes to the behavioral polymorphism, then E2 should affect behavior more in one morph than the other. Exogenous E2 administration enhanced aggression in WS birds, but not TS birds, suggesting that the behavioral polymorphism may be mediated in part by differential sensitivity to E2. Taken together, our studies are consistent with the hypothesis that ESR1 contains SNPs that lead to morph differences in ERα expression and that in turn, those differences in expression mediate morph differences in vocal aggression.

122.1 METZGER, DCH*; SCHULTE, PM; Univ. of British Columbia; *dmetzger@zoology.ubc.ca*

Maternal stress has divergent effects on gene expression patterns in the brains of male and female threespine stickleback

Maternal stress can have transgenerational consequences on the neurodevelopment and behavior of offspring that can influence offspring performance and population evolutionary trajectories. In this study we use threespine stickleback (*Gasterosteus aculeatus*), an important ecological and evolutionary model, to show that maternal stress has divergent effects on brain gene expression patterns in male and female offspring. Genes that were up-regulated by maternal stress in male offspring were down-regulated in females and vice versa. In males, genes that were up-regulated by maternal stress were enriched for processes involved in neural development and function, whereas in females genes that were up-regulated by maternal stress were enriched for processes involved in protein translation and metabolic functions. These data suggest that maternal stress has transgenerational effects on cellular pathways that differ depending on the sex of the offspring, which has important implications for assessing the long-term ecological and evolutionary impacts of stress across generations.

P3.90 MEZEBISH, TM*; NOVARRO, AJ; University of Maryland, College Park; *torimez@terpmail.umd.edu*

Heated Hunting: the Impacts of Temperature on the Optimal Foraging Strategy of the Eastern Red-Backed Salamander (Plethodon cinereus)?

Climate change can alter species' habitat and dietary requirements and can ultimately modify species' optimal foraging strategies. Optimal foraging theory suggests that animals adjust foraging preferences to maximize gains in energy per unit of time. The eastern red-backed salamander (*Plethodon cinereus*) preys on a wide variety of forest floor invertebrates and, as a lungless ectotherm, is highly dependent upon on cool and moist environments for gas exchange. Previous research describes the diet of P. cinereus, but does not consider the interaction between temperature and *P. cinereus* dietary preference. This study examined the impact of temperature on the dietary preferences of *P. cinereus* and tested whether foraging strategies affect body condition, a proxy for overall fitness. To investigate these questions, we offered three prey types to salamanders at 10 and 20°C. Prey types included crickets, mealworms, and legless crickets, which differ in fat content and aversion. We presented all prey types to each salamander for 48 hours and recorded the number of each prey type eaten every 12 hours. We repeated this procedure three times, recording body mass at the beginning and end of each trial to calculate change in body condition. Ectothermic species' fitness is maximized at temperatures just below thermal optimum for performance, allowing for more selective foraging. Thus, we predicted that *P. cinereus* prefers less aversive, high fat prey types at 10°C and are less selective at 20°C. If *P. cinereus* uses optimal foraging strategy to maximize energy gains at each trial temperature, we predicted that salamanders will maintain or increase body mass. Our results will motivate forest floor community and food web models to contribute to successful forest ecosystem conservation efforts in response to climate change.

54.2 MICHAELIDES, S*; WHILE, G; ULLER, T; University of Rhode Island , University of Tasmania, Australia, Lund University, Sweden; *msozos@gmail.com*

Colonization, Genetic Diversity and Fitness-related Consequences in Non-native Populations of Podarcis muralis in England.

Human activities are increasingly modifying the abundance and distribution of organisms and this is evident by the occurrence of numerous species beyond their native range. The common wall lizard, *Podarcis muralis*, has a wide distribution in Southern Europe. The species has also been repeatedly introduced in England with currently more than 25 extant populations. We used mtDNA sequences, microsatellite markers and a combination of Bayesian analytical techniques to unravel the colonisation history of the *P. muralis* in England. There were at least nine independent introduction events from native populations in France and Italy. We found evidence of admixture and support for secondary introductions within the non-native range. We further tested how introduction history influences genetic structure. Genetic diversity was significantly lower in England and for older non-native populations. The loss of genetic variation was greater for populations originating from sources with high levels of genetic diversity. There was no further loss in secondary introductions and admixture did not have significant positive effects. Finally, we collected data on hatching success from both native and introduced populations to assess the consequences of colonisation at the individual and population level. We found increased embryonic mortality in the non-native range indicative of inbreeding depression. Hatching failure was particularly high for populations with greater loss of genetic diversity. However, there was no evidence that heterozygosity is correlated with fitness at the population or individual levels. Combined, our study represents a comprehensive example linking introduction history, genetic diversity, individual fitness and population viability in a non-native species.

P1.71 MIDDLEBROOKS, ML*; EWEN, KA; DUETHMAN , MG; Univ. of Tampa; *mmiddlebrooks@ut.edu*

Unpalatability as a defense mechanism in the sacoglossan sea slugs Elysia clarki and Elysia chlorotica

Sacoglossans sea slugs are a group of shell-less marine gastropods. They are typically specialist herbivores living in close association with their algal food source. Several species of sacoglossan display kleptoplasty, the ability to photosynthesize using plastids sequestered from their algal food. While many small species live directly on their food and may use that as a form of crypsis, larger kleptoplastic species are often found to not be spatially associated with their algal food and thus may be at risk for predation. These larger non-cryptic species likely have other mechanisms to prevent predation such as chemical defenses. The sacoglossan sea slugs *Elysia clarki* and *E. chlorotica* were exposed to predators in the laboratory. Naive predators initially attempted to consume the slugs, although no slugs were completely consumed. Additional exposure caused predators to ignore or avoid the slugs altogether. This suggests that these sacoglossan species possess some means of chemical defense either acquired through their diet or directly synthesized by the animal.

S3.2 MIGUEL-ALIAGA, I; MRC Clinical Sciences Centre, Imperial College London, London, UK; *i.miguel-aliaga@imperial.ac.uk*

Organ plasticity, sex and reproduction

Internal organs are constantly exchanging signals, and can undergo profound anatomical and functional changes in response to them, even in fully developed organisms. Such organ plasticity results from a need to integrate and respond to both environmental information and internal state, and is key to maintaining homeostasis and driving adaptive changes. We are interested in understanding the mechanisms by which organs sense change and respond to it: the molecules, cellular events and physiological adaptations involved. The intestine and its neurons are a fantastic system with which to tackle these questions. Over the past few years, we have initiated the characterization of enteric neurons in *Drosophila melanogaster*, and have developed new technology for the study of their functions. Our investigations have uncovered evolutionarily conserved mechanisms of autonomic control, and have also characterized a novel and physiologically mechanism, reminiscent of neurovascular interactions in mammals, which points to a key role for the intestinal vasculature in adaptations to malnutrition. More recently, we have begun to explore the physiological plasticity of the intestinal epithelium - an obvious cellular target of the enteric neurons - both transcriptionally and metabolically. I will present some of this work, which has revealed unexpected sexual dimorphisms and intestinal contributions to reproductive success. I will also discuss some of our current work, aimed at 1) exploring the existence of cell-intrinsic sex differences in other fly cell types, mice and human cells, and 2) establishing their significance in the context of physiological adaptations and trade-offs.

106.4 MIKA, KM*; LYNCH, VJ; University of Chicago; *kmmika@uchicago.edu*

MIR Retrotransposons Rewired the GATA2 Regulatory Network in Decidual Stromal Cells

Previous work has suggested that transposable elements (TEs) have played a significant role in establishing the gene regulatory networks responsible for proper function of Decidual Stromal Cells (DSCs), an important pregnancy cell type at the maternal-fetal interface. Among the transcription factors that direct the hormone response in DSCS is GATA2. Here we show that three closely related TEs- MIR3, MIRb, and MIRc- were significantly enriched within GATA2 ChIPseq data in DSCs. These MIR elements are enriched for GATA2 binding sites, as well as binding sites for other transcription factors important for DSC function, such as HOXA10 and HOXA11. Finally we show GATA2 binding sites within the MIR elements are required for the MIR elements' abilities to regulate gene expression.

87.4 MIKUCKI, EE*; LOCKWOOD, BL; University of Vermont; *emikucki@uvm.edu*

Seasonal Differences in Diapause Induction in a Vermont Population of Pieris rapae Butterflies

Organisms that encounter heterogeneous environments must perform under a wide range of conditions. For butterflies from temperate regions, distinct seasonal morphs adapt to specific thermal environments that vary from month to month. Seasonal adaptations often result in season-specific phenotypes, such as the induction of diapause in autumn morph butterflies. Diapause is a state of hibernation characterized by decreased metabolic activity and developmental arrest. Diapause allows butterflies to tolerate the harsh winter conditions that are normally unsuitable for ectotherms. In the context of climate change, shifts in seasonality and increased frequency of temperature anomalies may expose seasonal morphs to unpredictable thermal environments to which they are not adapted. To better understand how individuals may respond to these seasonal and thermal challenges, we examined the diapause induction and termination in seasonal morphs of a Vermont population of *Pieris rapae*, the cabbage white butterfly. We found that diapause induction and termination in *P. rapae* is dependent on multiple environmental factors, including photoperiod and temperature. Moreover, diapause induction and termination depend not only on the conditions under which eggs and larvae are cultured, but also the conditions that diapausing pupae experience. Survival of diapausing pupae was negatively correlated with incubation temperature, suggesting that high temperature anomalies that occur in the winter may pose significant costs to this species. In addition, we present evidence of transgenerational effects on diapause. Taken together, our results suggest that diapause is a plastic trait that has evolved to be responsive to environmental change, but that warm winter temperature anomalies may impose limits on this species in the future.

P2.151 MILAM , AC*; LEONARD , JBK; Northern Michigan University ; *amilam@nmu.edu*

Habitat preference of juvenile lake sturgeon in the presence of brook trout at varying densities

Globally, sturgeon species are in severe decline as a result of habitat destruction, overfishing, and other impacts. Lake sturgeon, *Acipenser fulvescens*, is no exception; however, it is showing signs of recovery and is currently likely the most abundant North American species. As the largest fish and only species of sturgeon native to the Great Lakes basin, lake sturgeon rehabilitation is a pressing regional issue. Hatchery supplementation of the Great Lakes population has become a critical element of the population restoration plan. A key part of the supplementation process is the release of the juvenile sturgeon into streams that support survival and growth. There has been little research on the habitat (substrate) preferences or behavior in the presence of another species for hatchery-reared lake sturgeon . We conducted 12 h substrate preference tests in an artificial stream (two replicate sections) with sand, gravel, and rock substrates under 12:12 LL:DD photoperiod at approximately 12°C with low (four), medium (six), and high (eight) sturgeon densities. We then tested to see if these basic preferences were altered by the addition of one, two, or three brook trout (*Salvelinus fontinalis*) to the streams. We observed that juvenile lake sturgeon have a strong preference for the sand substrate and that this preference does not appear to be changed in the presence of brook trout.

143.5 MILES, DB*; SINERVO, B; HUEY, RB; MüLLER, J; LOVICH, J; MENDEZ DE LA CRUZ, F; RESENDIZ, R; ROSEN, P; Ohio University, Univ. California, Santa Cruz, Univ. Washington, Museum für Naturkunde, USGS, Southwest Biological Science Center, Universidad Nacional Autonoma de Mexico, Univ. Arizona; *urosaurus@gmail.com*

Desert tortoises race against climate change: past, present and future

Desert and gopher tortoises (*Gopherus*) are the sole survivors of a diverse tortoise fauna from the Cenozoic of North American but now face multiple anthropogenic threats including habitat destruction and climate warming. Because models predicting biotic impacts of climate have not integrated other anthropogenic stressors, and range-shift predictions lack validation against hot conditions expected by century's end, we develop ecophysiological-demographic models to identify populations at risk from simultaneous threats and predict range shifts under warming climates, past or future. Moreover, we use phylogenetic comparative methods to infer ancestral body temperatures and mode of thermoregulation. Tortoises evolved warmer body temperatures coincident with drying periods during the Miocene. Higher body temperatures coevolved with the invasion of grassland environments and an herbivorous diet. Models successfully recover distributions of extant *Gopherus* and even their Eocene ancestors - during the warmest period of the Cenozoic. Models forecast that Eocene-level warming by ~2080 may drive *Gopherus* extinct and that solar farms, which potentially limit warming globally, may paradoxically accelerate local extinctions. Nevertheless, widespread desertification of current agricultural areas by 2080 will create habitat - in regions where tortoise ancestors weathered previous hothouse episodes - into which tortoises can be translocated.

P3.106 MILES, M*; HAYES, LD; University of Tennessee-Chattanooga; *monica-miles@mocs.utc.edu*
Artiodacytl and Perrisodactyl Social Organization: Re-evaluation and Re-assessment
Social organization (size and composition of groups) influences how animals interact and is an important determinant of reproductive success. Recent comparative analyses of mammalian social organization have informed theory on the evolution of social traits. While an important first step to understanding the evolutionary drivers of mammalian social organization, these analyses were based on datasets derived largely from secondary sources and lacked information on intraspecific variation in social organization. Our aims were to (1) re-evaluate the social organization of ungulates (Orders: Artiodactyla and Perissodactyla), comparing trends gleaned from the primary literature to trends in recently published databases on mammalian social organization and (2) determine the extent of intraspecific variation in social organization across ungulates. Using Web of Science, we searched the primary literature on ungulates for information on social organization (solitary, group-living), including intraspecific variation within and between populations. We found information on social organization for 105 artiodactyls (56%) and 12 perrisodactyls (75%). Of these species, 91% were found to be social compared to 56% in a recently published database on mammalian social organization. Intraspecific variation in social organization was observed within populations (22/117 species), between populations (2/117), and for both within and between populations (71/117). Our results highlight the importance of using primary sources of data and considering intraspecific variation in social traits when preparing datasets for comparative analyses.

103.8 MILLER, LP*; DOWD, WW; San Jose State University, Loyola Marymount University; *luke.miller@sjsu.edu*
Valve gaping behavior and body orientation of mussels in different microhabitats on wave-swept rocky shores
The simple behavioral repertoire of mussels includes gaping, which facilitates feeding and oxygen exchange, and possibly reorientation of the body posture via the foot and byssal system. Gaping behavior in subtidal habitats is often driven by external factors such as food availability, diel cycles, or predator presence. In intertidal habitats, where bivalves such as Mytilus californianus are repeatedly exposed to aerial conditions, valve closure can serve the additional function of limiting desiccation, although at the cost of a transition to anaerobic metabolism. Using an electronic datalogging system, we have tracked the valve gaping behavior, body orientation, and mantle cavity temperatures of mussels in different microhabitats on an open coast rocky shore. The predominant pattern in shell gaping is aligned with the circatidal rhythm for mussels living at two intertidal heights and for those in a tidepool. In microhabitats with longer submersion times, there is a secondary peak in gaping behavior more closely aligned with the diel cycle. Unlike some related mussel species, there is little evidence of valve gaping during peak low tide temperatures (31-38 °C), indicating that M. californianus may favor desiccation avoidance over evaporative cooling during thermal stress events. We observed minimal movement or re-orientation of focal mussels within our experimental beds over time scales of days to weeks, despite significant inter-individual variation in maximum body temperatures. When aligned with temperature records and physiological measurements, these monitoring data will allow us to estimate which environmental and behavioral factors contribute most to the physiological performance and survival of mussels living in highly variable intertidal environments.

P2.162 MILLER, CH*; CAMPBELL, P; SHEEHAN, MJ; Cornell University, Oklahoma State University; *chm79@cornell.edu*
Vomeronasal Receptor Evolution: Transcriptomics Approach to Investigate Signal Diversity and Individual Recognition
The mouse olfactory system is an ideal system for investigating the genetic and neural mechanisms underlying diverse behavioral responses. There are currently over 530 functional vomeronasal receptors, as well as a large array of corresponding pheromone ligands. In the last ten years, the gene families of receptors and ligands in the mouse reference genome have become more well-described. It is now possible to more robustly investigate the diversity of olfactory receptors and ligands across mouse species and subspecies. We use deep RNA sequencing to develop transcriptomes for vomeronasal organ and liver tissues of six strains of mice. By examining the evolutionary patterns and selective pressures at play in the receptor-ligand diversity in the mouse olfactory system across species, we can better understand the genetic logic behind complex social behaviors, such as individual recognition. More specifically, understanding the receptor-ligand complement across mouse species will help create a framework in which to investigate the neural mechanisms for signal detection and the encoding of complex social information and chemosensory cues.

P3.98 MILLER, S*; SHUKLA, D; WILCZYNSKI, W; Georgia State University; *smiller68@student.gsu.edu*
Effects of Social Hierarchy on Simulated Aggression and Exploratory Behavior in Green Anoles
Male green anoles (*Anolis carolinensis*) establish dominance relationships within minutes of interacting with other males. Acquisition and maintenance of social status over a period of time results in physiological changes influencing an array of behaviors including aggression, courtship and self-preservation behavior. Here we examined the influence of social status in male anoles on aggression and exploratory behavior. Size and weight matched males were paired to allow the formation of dominant-subordinate dyads and were tested for aggression and exploratory behavior 6 days after pairing. The same animals were also tested 6 days before pairing to evaluate preexisting differences in these behaviors. For the aggression test, a mirror was used to simulate the presence of an intruder and the number of aggressive acts was quantified. For the exploratory behavior test, an arena was separated by a divider into two chambers: a dark, smaller acclimation chamber and an illuminated, larger test area that included perches. The animals were allowed to explore the test area for 40 minutes. The time spent in the test area and on the perches was recorded. Subordinates were found to be significantly less aggressive than dominants following the establishment of hierarchy (paired t test: $t=3.645$, $p=0.0039$). Furthermore, both dominants (D) and subordinates (S) had lower levels of aggression relative to their pre-pair levels (paired t tests: D:$p=0.0014$, $t=4.226$; S: $p= 0.0018$, $t=4.097$). Acquisition of social status had no affect on exploratory behavior. Interestingly after acquisition of social status, future subordinates spent significantly less time in the test area ($t=2.573$, $p=0.022$). Thus, while social hierarchy influences aggression it has no affect on general exploratory behavior.

2.5 MILLER, L/A*; JONES, S; University of North Carolina; *lam9@unc.edu*

The role of bristles in wing-wing interactions

The smallest flying insects commonly possess wings with long bristles. Little quantitative information is available on the morphology of these bristles, and the functional importance of these bristles remains a mystery. In this study, we (1) collected morphological data on the bristles of 23 species of Mymaridae by analyzing high-resolution photographs and (2) used the immersed boundary method to determine via numerical simulation if bristled wings reduced the force required to fling the wings apart while still maintaining lift. The effects of Reynolds number, angle of attack, bristle spacing, and wing-wing interactions were investigated. In the morphological study, we found that as the body length of Mymaridae decreases, the diameter and gap between bristles decreases and the percent of the wing area covered by bristles increases. In the numerical study, we found that a bristled wing experiences less force than a solid wing. The decrease in force with increasing gap-to-diameter ratio is greater at higher angles of attack than at lower angles of attack, suggesting that bristled wings may act more like solid wings at lower angles of attack than they do at higher angles of attack. In wing-wing interactions, bristled wings significantly decrease the drag required to fling two wings apart compared with solid wings, especially at lower Reynolds numbers. These results support the idea that bristles may offer an aerodynamic benefit during clap and fling in tiny insects.

P2.241 MILLER, RL*; BROWN, CJ; CLOSE, MT; COOPER-BAILEY, K; Radford University; *rmiller21@radford.edu*

Anesthesia in Terrestrial Salamanders: Are All Modes Equal?

Anesthetic drugs vary in their ability to induce and maintain anesthesia in animals due to variability in the form and function of the respiratory and cardiovascular systems. Because amphibians respire through their skin, immersion anesthetics have long been a standard method of anesthesia delivery for many species. However, because most amphibians are also capable of gas exchange through the buccopharyngeal cavity and lungs, we asked the question of whether all anesthetics were equally effective in amphibians that rely less on cutaneous gas exchange and more on bucco-pulmonary gas exchange. We compared the effects of injectable, inhalant, and immersion anesthetics in adult tiger salamanders (*Ambystoma mavortium*) in their ability to induce anesthesia. We administered anesthetics at several concentrations commonly used in research and veterinary medicine, and measured the effects on heart rate, respiratory rate and time to sedation, induction and recovery as compared to controls. We found that when compared to controls, none of the anesthetics affected heart rate, and all suppressed respiratory rate. Additionally, both injection and immersion anesthetics had cases of slow or no induction of anesthesia at low concentrations, but were effective at high concentrations. Immersion anesthetics had the highest variation in variables tested and had longer induction and recovery times when compared to injection anesthetics. We conclude that immersion, inhalant and injection anesthetics are all sufficient to induce anesthesia in terrestrial lunged salamanders, but that they are not all equal in their induction and recovery times or in their degree of variation. These results suggest that the method of anesthesia be evaluated in species prior to carrying out research with large samples.

P1.286 MINCZUK, KE*; LEVIYEVA, J; OUFIERO, CE; Towson University; *kmincz1@students.towson.edu*

Interspecific Variation in the Strike Kinematics and Feeding Behavior of Praying Mantises

The order Mantodea consists of over 2,300 species of insects that have two spiked, enlarged, grasping (raptorial) forelegs, which are moved in a coordinated fashion to capture prey. Mantis specialization and diversification of morphology and behavior in response to various environments has led to ambush, generalist, and cursorial hunting strategies. Previous Mantis studies have focused on vision and prey recognition or courtship and mating behavior, yet there has been little to no research concentrating on the kinematics of the feeding strikes across the spectrum of species. The mantis method of predation typically consists of a period of visual pursuit, approach, rapid capture or sweep, and ingestion of prey. The goal of this study is to examine the interspecific variation in the strike kinematics and feeding behavior of praying mantises. Species comparisons between the ghost mantis (*Phyllocrania paradoxa*), Carolina mantis (*Stagmomantis carolina*), Chinese mantis (*Tenodera sinensis*), and thistle mantis (*Blepharopus mendica*) were conducted by evaluating the feeding strikes of 1-5 individuals per species at the last juvenile stage (instar 6) and the adult life stage (instar 7). Feeding strikes were filmed at 1000 Hz with a high-speed camera, and several points on each video were digitized to measure foreleg and body size, as well as determine the movement of the coxa, trochanter-femur, and tibia of the raptorial foreleg, and body lunge to calculate strike kinematics. Kinematics, including angles, angular velocity, amount of lunge, and timing of events will be compared across species. Results will be discussed in the context of morphology, ecology and life-style of the mantises to determine if the detailed kinematics are similar across species or if components of the strikes vary. These results will provide information on the amount of diversity associated with a complex functional system.

P2.29 MINER, MR*; GOTHMANN, AM; GAGNON, AC; Western Washington University, University of Washington; *maxminer3@gmail.com*

Effects of Carbonate Chemistry on Calcification in the Orange Cup Coral, Balanophyllia elegans

Ocean acidification (OA) is characterized by dramatic changes in ocean carbonate chemistry. In particular, seawater pH and saturation state with respect to aragonite (Ω) decrease, and seawater pCO_2 and DIC increase. While OA is generally understood to be harmful to calcifying organisms, overall responses of to OA vary greatly across taxa, making it difficult to predict how organisms will fare under continued environmental change. Cold-water scleractinian corals (CWC) generally tend to dwell in waters with relatively low pH and Ω. In addition, CWCs lack photosynthetic symbionts, which allows for the isolation of calcification processes from photosynthesis.

In this study, we investigated the calcification response of the orange cup coral, Balanophyllia elegans, to changes in shifting carbonate system parameters. In experimental treatments, dissolved inorganic carbon (DIC) and pH were manipulated independently, with seawater set at nine different conditions: one at ambient DIC and pH, four at stable pH with varied DIC, and four at stable DIC with varied pH. Net calcification rates were determined using alkalinity anomaly. Large variations in calcification rate were seen at stable pH when DIC was varied, and vice versa. Aragonite saturation state was found to most closely control calcification.

Our findings agree with previous research[1] on tropical coral that has found aragonite saturation state to be the dominant parameter controlling calcification in scleractinian coral. However, results also suggests that CWCs have the may calcify at lower saturation states than tropical coral.

[1]Schneider, K., Erez, J.. The effect of carbonate chemistry on calcification and photosynthesis in the hermatypic coral Acropora eurystoma. Limnology and Oceanography. 51(3), 2006, 1284-1293.

14.3 MINICOZZI, M*; PEREZ, J; SUMMERS, A; GIBB, A C; Northern Arizona University, University of Washington; *mrm539@nau.edu*

It's only a flesh wound! Puncture force scaling in flatfishes

Fish scales interact with the external environment and have evolved to meet the physical demands of the animal, including attacks from predators. Flatfishes are unusual because they have left-right asymmetry of their bodies (eyed vs. blind sides), and the two sides may be under different selective pressures. We used three species of flatfish (*Parophrys vetulus, Isopsetta isolepis* and *Platichthys stellatus*) from different habitats (soft-bottomed vs. gravel) to address questions related to resistance to puncture force (a proxy for predator attack or environmental insult). Is the force required to puncture the scales similar across species? Does puncture force differ between the eyed and blind sides? How does puncture force change as fish grow larger? We predicted that *Platichthys* would require the greatest force to puncture the scales+skin because the species is less cryptic, can be found on a gravel substrate, and has the largest scales of the three species. In addition, we predicted that the eyed side of each species would require a larger puncture force because it is more exposed to the environment and potential predators, relative to the blind side. We found that *Platichthys* scales require the greatest puncture force (~2x force for comparably sized individuals) of all three taxa. We also found no significant differences between the eyed and blind sides of any flatfish species. Puncture force scaled directly with body length in two of the three species, but sub-linearly (relative to length) in the third species (*Isopsetta isolepis*). We hypothesize that, as fish grow larger, scales increase in thickness, and the additional material yields increased resistance to puncture forces. Ongoing studies considering the relationship between body size, scale thickness, and morphology may reveal the physical parameters that underlie differences in the puncture forces among flatfishes.

133.3 MIRE, P*; CAVANAUGH, M; Univ. of Louisiana, Lafayette; *pmire@louisiana.edu*

Dynamics of Cnidocyte Types in Development of Nematostella vectensis

Sea anemones employ cnidae, specialized capsules produced in cnidocytes, to capture prey. Anemones develop from planula larvae to polyps that form tentacles containing cnidae. Two types of cnida occur in tentacles, adhesive spirocysts and penetrant nematocysts. We characterized cnidae during developmental stages in the model sea anemone, *Nematostella vectensis*, using spirocysts density:nematocyst density ratios. Planulae contain only nematocysts and no spirocysts (ratio 0.00). Spirocysts first appear in primary polyps coinciding with the formation of 4 tentacles but are far outnumbered by nematocysts (ratio 0.46+ 0.04). Spirocysts increase in density as polyps develop 5-10 tentacles but nematocysts remain the dominant cnida type (ratio 0.65+ 0.16). In adults having 16 tentacles, spirocysts outnumber nematocysts in tentacles (ratio 2.19+ 0.38). Thus, the formation of spirocysts is delayed compared to nematocysts in developing anemones and continues through polyp maturation. Pattern formation in epithelia often involves Delta-Notch signaling and this pathway has been implicated in cnidogenesis in planulae. We asked whether Notch signaling is involved in the differentiation of cells that form spirocysts (spirocytes) during polyp maturation. We inhibited Notch in polyps with 5-10 tentacles with DAPT. DAPT treatment resulted in no significant change in the mean spirocyst:nematocyst ratio (0.54+ 0.08) but resulted in a decrease of overall cnidae abundance. Our results suggest that the Delta-Notch pathway is involved in the regulation of cnidogenesis in maturing polyps. Continuing experiments are resolving if another cell type increases upon inhibiting Delta-Notch and the identity of the presumed cell type. (See companion abstract, "Hair Bundle Abundance in *Nematostella vectensis* is Regulated by Delta-Notch")

83.5 MISTICK, EA*; CLARK, CJ; Univ. of California, Riverside; *emilymistick@gmail.com*

Male hummingbirds use kinematics to control sound signaling in diving courtship display

Male hummingbirds produce loud sounds with their tail-feathers for females during a 'dive display' in which the male ascends then dives toward the female at high speed. As he performs this maneuver he spreads his tail feathers, which produce a loud tonal sound via aeroelastic flutter. The physical acoustics of this display is complex and depends both on the physical acoustics of feather flutter and on male behavior. We sought to understand how the male controls both the loudness and frequency of the sound he emits and of the sound the female receives. Wind tunnel experiments show that loudness depends on receiving angle (sound field is a directional, dipole-like, pattern), and that loudness and sound frequency depend on airspeed. Therefore, sound the female receives depends on elements of the male's chosen trajectory: his speed, angle and distance from her as well as a Doppler shift in the sound. We tested a series of predictions about the sound field using an "acoustic camera", which spatially maps sound sources onto visual frames.

47.1 MITCHELL, JM*; NICHOLS, SA; University of Denver; *yinnismc@gmail.com*

Roles of the vinculin family proteins in the sponge Ephydatia muelleri

Cell adhesion is a key feature of the multicellular ancestor that was definitive for the origin of Metazoa. Although many of the major cell adhesion systems are ubiquitous and their components were present in the metazoan unicellular ancestors, little is known when and how some of these proteins started to form functional adhesion complexes and/or co-opted to their current functions. The vinculin family of proteins is key to cell-to-cell and cell-to-ECM adhesion complexes. This family includes α-catenin and vinculins, which are well studied in model bilaterian systems, where they regulate actin-based structures, including cadherin- and integrin-based cell adhesions. However, we know nothing about their function in non-bilaterian animals, such as sponges, which could offer a valuable insight into the evolutionary history of these proteins. Here, we examine the function and tissue/subcellular localization of two vinculin-family proteins in the freshwater sponge *Ephydatia muelleri*. For Vin-1 (a homolog of vinculin), we found evidence for two different cellular populations that function in adherens junctions (cadherin-based cell adhesion) and focal adhesions (integrin based adhesions); these data represent the first experimental molecular evidence for the presence of cell junctions in sponge tissues. In contrast, Vin-2 (an uncharacterized Vin family protein present in all animal clades except vertebrates) was found to localize to the microtubule organizing center (MTOC). Taking into account that choanoflagellates only have one vinculin homolog, which also localizes to the MTOC, these data suggest that genome duplications in the metazoan stem-lineage led to the origin of vinculin and alpha-catenin from a Vin-2-like ancestral protein, which functioned at the MTOC.

105.2 MITCHELL, T.S.*; WARNER, D.A.; JANZEN, F.J.; Auburn, Iowa State University; *tsm0024@auburn.edu*

Do covariances between maternal behavior and embryonic physiology drive sex-ratio evolution under environmental sex determination?

Fisherian sex-ratio theory predicts sexual species should have a balanced primary sex ratio. However, organisms with environmental sex determination (ESD) are particularly vulnerable to sex ratio skews as environmental conditions are variable. Theoretical work has modeled sex-ratio dynamics for animals with ESD with regard to two traits predicted to be responsive to sex-ratio selection: (1) maternal nest-site choice and (2) sensitivity of embryonic sex determination to environmental conditions, and much research has since focused on how these traits influence offspring sex ratios. However, relatively few studies have estimated univariate quantitative genetic parameters for these two traits, and the existence of phenotypic or genetic covariances among these traits has not been assessed. Here, we leverage studies on three species of reptiles (two turtle species and a lizard) with temperature-dependent sex determination (TSD) to assess the phenotypic covariance between maternal nest-site choice and the thermal sensitivity of the sex-determining pathway. These studies measured maternal nesting behaviors that relate to nest temperature, and assessed the sex ratio of offspring incubated under controlled conditions. A strong covariance between these traits would maximize the efficiency of sex-ratio selection. However our results indicated no such covariance between nest-site choice and thermal sensitivity in the three study species. These results suggest that nest-site choice and thermal sensitivity of sex determination are able to evolve independently. Such information is critical to understand how animals with TSD will respond to rapidly changing climate.

P1.237 MOBERLY, IT*; MOON, BR; University of Louisiana at Lafayette; *itm3905@louisiana.edu*

The Contributions of Setae to Gripping Force and Locomotor Stability in an Arboreal Lizard (Furcifer oustaleti)

Arboreal habitats present some of the greatest challenges to movement, as they contain complex arrangements of perches with various diameters, inclines, and spacing. Due to the increased chance of toppling, maintaining stability is of primary importance in arboreal locomotion. Chameleons are largely arboreal specialists and possess diverse characteristics that enable them to move smoothly through their complex environments. For example, their zygodactylous feet and prehensile tails have friction-enhancing microstructure (setae) on the substrate-contacting surfaces, allowing for effective gripping. This research examines the importance of subdigital setae on gripping performance in Oustalet's chameleons (*Furcifer oustaleti*). To explore the functional significance of setae in arboreal locomotion, I measured the gripping performance and locomotor movements of chameleons before and after interfering with the setae. I recorded the chameleons moving across perches of different diameters, hardnesses, and inclines to assess the conditions in which setae provide the most benefit in maintaining stability.

99.6 MOEN, DS*; HANSON, DK; Oklahoma State University; *daniel.moen@okstate.edu*

Functional Redundancy Permits Morphological Differences Between Frog Ecomorphs Without Reducing Performance

Why do organisms with similar ecologies often have similar morphology? Evolution of morphology usually results from selection on functional performance, so to answer this question we need to understand the relationship between form and function. Furthermore, within a given group of organisms (e.g. frogs), selection may favor high performance in general behaviors shared by many species (e.g. jumping) and also high performance in environment-specific behaviors (e.g. swimming, burrowing) in only a subset. Thus, does the morphology of a species that uses multiple environments reflect performance tradeoffs across those environments? Or does functional redundancy (many-to-one mapping) permit morphology that produces high performance in multiple behaviors? Here, we study the relationship between morphology and performance in 44 species of anurans (frogs and toads) that inhabit different microhabitats (i.e. different ecomorphs) and examine how that relationship may explain their distinctive morphology. We first test whether anuran ecomorphs differ in jumping and swimming performance and leg morphology. We then estimate the relationships among relative leg length, relative leg muscle mass, and performance in jumping and swimming. Finally, we combine these results to examine whether functional redundancy explains the morphology of the different ecomorphs. We find that long legs and muscular legs both increase jumping and swimming performance, but their relative importance for the two behaviors dictates which form (especially long or especially muscular legs) best describes anurans in different microhabitats. Thus, functional redundancy, rather than performance tradeoffs, better explains the leg morphology of frogs in different microhabitats.

P2.93 MOGUS, JP*; AMATO, CM; MCCOY, KA; East Carolina University; *mogusj15@students.ecu.edu*

Characterization of Sex Hormone Binding Protein Alpha-fetoprotein Production During Natural Sexual Differentiation and Endocrine Disruption.

The correct milieu, concentration, and timing of exposure to sex hormones are essential for normal development of sexually dimorphic tissue structure and function (e.g., penis vs. vagina). Alpha-1-fetoprotein (AFP), is a sex steroid binding protein produced by the fetal liver, that binds circulating estrogens with high affinity, regulating its transport to tissues. Despite its necessity for fetal steroid regulation, AFP has not been quantified throughout sexual differentiation in the mouse model, which limits our ability to fully understand and characterize the role that endogenous sex hormones play in sexual dimorphic development. In addition, a number of pollutants, called endocrine disrupting chemicals (EDCs), are known to alter steroidogenesis and receptor-ligand interactions. However, the way in which transport proteins, like AFP are altered by EDC exposure remains relatively unexplored. To address these deficits, we quantify fetal liver AFP concentrations, and bound and free sex hormone concentrations in the mouse via validated ELISAs during sexual differentiation (embryonic days (E) 14.5-17.5). In addition, we exposed pregnant dams during this same time period to the model EDC vinclozolin (125mg/kg) and quantified liver AFP and sex hormone concentrations in male and female fetuses at E17.5. We characterized sex specific AFP concentrations across time and between control and vinclozolin exposed embryos and directly link AFP quantity with bound vs. free sex hormone concentrations. Understanding the dynamic nature between AFP and sex hormone binding across time in males and females as well as how these relationships are altered by EDCs will provide foundational information that will help redefine the mechanisms through which pollutants can alter endocrine function.

P2.276 MOHAMADZADEASL, A; KHODABANDEH, S*; Univ. of Tarbiat Modares; *surp78@gmail.com*

Anti-oxidant properties of Sea cucumber, Holothuria parva, muscle peptides

Marine animals, due to have secondary metabolites, are the main bioactive materials sources with different activities including; antioxidant, anti-cancer, anti-bacterial and anti-inflammatory effects. In the present study, the sea cucumber, *Holothuria parva*, muscles were hydrolyzed by using of Bacterial Alcalase enzyme (with 1.5 percent). First 50 grams of sea cucumber fresh minced muscle was hydrolyzed and then, total hydrolyzed protein ultra-filtrated by using of ultra-high molecular weight Millipore filters (30, 10 and 3). Protein content was also measured in total hydrolyze and in the fractions (with >30, 10-30, 3-10 and <3 kDa weights) by BCA (bicinchoninic acid) method. The results showed that the amount of protein in the fraction of >30 kDa, 10-30, 3-10 and <3 was 47.33, 57.08, 47.66, and 15.5 mg/ml, respectively. Then, their antioxidant activity was evaluated by hydroxyl radical (OH) and Ferric reducing anti oxidant power (FRAP) in 10 mg of each fractions. Results showed that, the anti oxidant activity of total hydrolyze protein, >30, 10-30, 3-10 and <3 kDa is 48, 13, 15, 22, 35 u/ml, respectively. In FRAP method their antioxidant activities were 229, 54.5, 48, 72.6 and 146.9 unite for total hydrolyze, >30, 10-30, 3-10 and <3 kDa, respectively. Overall our results showed that, the peptides, derived from the hydrolysis protein of sea cucumber muscle, possess antioxidant activity and this bioactivity is significantly higher in the peptides with smaller molecular weights.

82.7 MOHAN, U*; MAITRI, M; SANE, S P; National Centre for Biological Sciences, TIFR, India; *umeshm@ncbs.res.in*

Visual and Mechanosensory Integration by Descending Interneurons in Hawkmoths

Flying insects use sensory cues from multiple modalities to control their flight. They must acquire, process and respond to perturbations within a few wing beats to ensure stable flight. In the nocturnal hawkmoth *Manduca sexta*, mechanosensory input from antenna has been shown to be critical for stable flight. These moths also make use of visual inputs to control their flight. The acquisition and processing of visual cues is typically slower than mechanosensory cues in nocturnal insects due to low light levels. How are these multimodal sensory cues integrated by nervous system for rapid flight control? We hypothesized that multiple sensory cues converge to fewer descending interneurons that integrate, process and transmit sensory information to the thoracic ganglion. An alternative (but not mutually exclusive) hypothesis is that such information is transmitted via parallel channels and integrated in the thoracic ganglion. To address these hypotheses, we recorded intracellularly from axons of descending interneurons in the ventral nerve cord of the nocturnal hawkmoth *Daphnis nerii*. We identified multiple classes of descending interneurons which respond in a tuned manner to both individual and combinatorial mechanical and visual inputs. Together, these data show that descending interneurons integrate multimodal cues, often displaying very specific tuning properties which suggest their specific physiological contribution to flight stabilization.

P1.193 MOHR, RA*; COX, TC; SISNEROS, JA; University of Washington, Seattle, University of Washington, Seattle; Seattle Children's Research Institute, Washington; *rmohr916@uw.edu*

Sexually Dimorphic Swim Bladders Suggest an Adaptation for Enhanced Sound Pressure Detection in the Plainfin Midshipman Fish (Porichthys notatus)

Swim bladders have evolved multiple functions not limited to maintaining buoyancy and hydrostatic position in the water column. Direct and indirect connections between the swim bladder and inner ear yield increased hearing abilities when the gas-filled swim bladder transduces pressure-induced vibrations to the inner ear and enables sound pressure detection. In the plainfin midshipman fish, *Porichthys notatus*, nesting type I males attract females via a multi-harmonic advertisement call known as a ‘hum'. The hum not only attracts females but also type II males or ‘sneakers' that must also localize type I nests to cuckold and steal fertilizations from type I males that are actively courting females. Recent swim bladder deflation experiments show that the swim bladder is likely necessary for near field sound localization by female midshipman fish. Here we show the first evidence of inter-and intrasexual differences in swim bladder morphology. Micro-CT images reveal bilateral dorsal ‘horn-like' projections of the swim bladder in both females and type II males which are absent in type I males. Measurements from the rostral most point of the swim bladder to the caudal ends of the three inner ear end organs confirm that females and type II males have significantly shorter distances between these structures than that observed for type I males, strongly suggesting enhanced pressure sensitivity, which may function to increase the detection and localization of vocalizing conspecifics during the breeding season.

136.7 MOHREN, TL*; CALLAHAM, J; PRATT, BD; BRUNTON, BW; DANIEL, TL; University of Washington, University of Massachusetts, University of Washington; *tlmohren@uw.edu*

Sparse sensing by arrays of wing mechanosensors for insect flight control

Compared to even the best engineered systems, insects control their flight faster, more robustly, and with greater energetic efficiency. In contrast to engineered systems, recent research suggests insect wing flapping serves the dual roles of both actuation and sensing. Sensory information is acquired by mechanoreceptors that are present on the wings of all insect taxa. These receptors respond to wing strains that result from the combination of flapping motions and body rotations. How the ensemble of wing strain sensors relate local strain information to a control decision remains an open question. We hypothesize that, to control their flight, insects can more robustly determine inertial rotations if those rotational velocities are classified into distinct regimes. To test this hypothesis, we use experimentally determined neural encoding properties of wing mechanoreceptors along with a sparse sensor placement algorithm, and the structural simulation of a model insect wing. We provide our model wing with an array of 25 strain sensors. We can then classify the perturbation to one out of 5 distinct rotational velocities about the yaw axis: [0,5,10,15,20] rad/s. The firing rate of each sensor is weighted and the velocity is determined by linear discriminant analysis. In our simulation, the wing undergoes smooth angular velocity perturbations during 3 seconds, while the combined array of sensors selects one out of the 5 discrete angular velocities at 1 kHz frequency. The model predicts that angular velocity can be discriminated with a mean error of 2.9 rad/s. We suggest that, by sacrificing sensitivity to small velocity changes, the insect can reject sensor uncertainty, thereby increasing the robustness of control output.

P3.189 MOLINA, EM*; WROBEL, ER; NAVARA, KJ; MENDONCA, MT; Auburn University, Georgia University; *emm0044@auburn.edu*

AR Concentration in the Germinal Disc Region of the Hen (Gallus gallus).

Numerous studies have demonstrated that female birds can skew the primary sex ratio of their offspring, with biases occurring prior to ovulation of the follicle. However, the precise mechanism by which this pre-ovulatory selection occurs is unknown. Administration of exogenous steroid (i.e. progesterone, corticosterone, or testosterone) to females of several species of birds has proven effective in skewing primary sex ratios. Several studies have found testosterone treatment during the ovulatory cycle produces a male biased sex ratio, suggesting that androgen receptors (ARs) associated with the follicular cells or the germinal disc are mediating the mechanisms involved in skewing sex ratio. If ARs are important in this mechanism, we would predict changes in AR dynamics in relation to the timing of meiotic segregation (3-5 h prior to ovulation), compared to other times during the ovulatory cycle. We would further predict that these changes would be more dramatic in the germinal disc (oocyte) area than in adjoining follicular cells. We monitored oviposition patterns in 400 chickens 5 times a day for 5 weeks to identify 60 hens that were laying consistently. We collected F1 follicles just before the time of expected meiotic segregation and then a time point well before meiotic segregation (N=30/each) for AR protein analysis using Western blots. Preliminary results indicate that AR concentration is higher in GD collected near the time of meiotic segregation versus well before this time frame (2.09±1.0 vs. 1.68±0.81; p=0.045). Determining the timing of AR upregulation in relation to meiotic division could provide further insight into the hormonal mechanisms controlling meiotic segregation and factors controlling sex ratio in birds.

P1.137 MONTREUIL-SPENCER, C*; SCHOENEMANN, K; BONIER, F; Queen's University, Kingston, Ontario; *9cm54@queensu.ca*

Winter Physiology, Summer Breeding: Is There A Link?

Reproduction is an energetically demanding activity in all organisms. In natural populations, some individuals invest more in reproduction, while others invest more in self-maintenance. To understand this individual variation, most studies have investigated the relationship between self-maintenance and reproduction within one life history stage. However, conditions experienced at one point in an individual's life might carry-over across stages, and have implications for future investment. The degree to which traits associated with self-maintenance during the non-breeding season predict reproductive investment during the breeding season is poorly understood. We studied free-ranging black-capped chickadees (*Poecile atricapillus*) to determine if individual variation in physiological traits (e.g., glucocorticoid hormone levels, oxidative stress, and immune function) during winter predict variation in reproductive traits (e.g., clutch size, egg mass, parental care behavior) during the subsequent breeding season. We present results of correlative analyses between overwintering chickadee physiological traits and reproductive traits to better understand whether self-maintenance during winter and reproductive effort represent competing functions across life history stages, or whether some individuals can maximize both, suggesting individual variation might be driven more by quality, condition, or resource acquisition. By integrating physiology and behavior, and evaluating carry-over effects across stages, we can better interpret individual variation in traits relating to self-maintenance and reproduction to gain a more complete understanding of life history strategies.

54.3 MOODY, KN*; BLUM, MJ; BLOB, RW; PTACEK, MB; Tulane University, Clemson University, Clemson University; *kmoody3@tulane.edu*

Connectivity matters: integrating genomics with models of dispersal and selection yields new insights into population divergence in a Hawaiian waterfall-climbing goby.

Deciphering evolutionary and ecological factors that contribute to population divergence has been challenging in marine species, which oftentimes have few barriers to dispersal and low levels of population differentiation. However, environmental variables such as oceanic currents and post-settlement habitat differences can reduce gene flow resulting in fine-scale genetic structure, particularly at loci under selection. The waterfall-climbing Hawaiian goby fish, *Sicyopterus stimpsoni*, has a marine larval dispersing phase yet experiences post-settlement selection (predation and climbing), which varies in disparity with stream geomorphology and corresponds to observed differences in body shape. Here, we analyzed population structure of *S. stimpsoni* across the archipelago by combing genotyping by sequencing with oceanographic models of passive dispersal and individuals-based models of natural selection. Neutral loci showed low, fluctuating, yet significant genetic structure, whereas loci potentially under selection showed strong genetic structure between populations with different post-settlement selective regimes. However, mismatches between our model connectivity matrices and observed patterns of population structure demonstrated that when either local retention or self-recruitment is increased, combined with post-settlement selection, our fit between simulated and observed patterns of genetic structure improves. Our results suggest that comparing observed patterns of population differentiation to models of gene flow, drift and selection yields new insights into how populations of marine dispersing organisms may diverge and potentially lead to speciation in an environment conducive to high connectivity.

P3.227 MOON, B.R.*; SPANGHERO VICENTE FERREIRA, G; PENNING, D.A.; University of Louisiana at Lafayette, Instituto de Biociências, Letras e Ciências Exatas - UNESP/IBILCE, Missouri Southern State University; *bradmoon@louisiana.edu*

High Performance in a Tight Spot: Kingsnake Pinioning Pressures in Simulated Tunnels

Many predators feed in microenvironments that may constrain their movements and obscure or block our observation and study. For example, constricting snakes probably often feed on mammals underground in tunnels, where space may be too limited for typical coiling and constriction. In such circumstances, some snakes will press prey against the wall of a tunnel with part of the snake's body, in a predatory behavior that has been called "pinioning." Pinioning serves the same purposes as constriction, to restrain and incapacitate prey before ingestion. However, pinioning behavior is not well known and pinioning performance in tunnels has not yet been quantified or compared to typical constriction on open surfaces. We measured the pinioning pressures of kingsnakes in simulated tunnels and compared them to typical constriction pressures on the surface. Pinioning and constriction pressures are good measures of predation performance because they reflect a key variable (pressure) that can directly incapacitate the prey. We found that pinioning pressures in tunnels were higher than constriction pressures on open surfaces. These results indicate that snakes can exert impressively high predation pressures underground as well as on the surface, and more generally that predation performance is not always reduced in microenvironments that impose constraints on predatory movements.

33.3 MOORE, JM*; OSBORN, KJ; Florida Museum of Natural History, University of Florida, National Museum of Natural History, Smithsonian Institution; *jmoore@ufl.edu*

Revealing the Identity of the Model Organism Chaetopterus sp. (Annelida)

Chaetopterus is one of the most bizarre and readily recognized clades of marine Annelida. Members of the genus have evolved a remarkably tagmatized body plan, specialized for mucus-net suspension feeding. While *Chaetopterus* species have been used extensively as model organisms in studies of development, biomechanics, and biomedicine, the systematics of the genus remain problematic. Within the genus, morphological specialization to mucus-net suspension feeding contributes to low interspecific variation, while morphological plasticity and enormous regenerative capacity heighten intraspecific variability. As a result, all 23 species described before 2001 were synonymized at one time or another with the Mediterranean species *Chaetopterus variopedatus*, long considered a morphologically variable, cosmopolitan species. While some names have recently been resurrected from synonymy, the identities of *Chaetopterus variopedatus*, the type species *C. pergamentaceus*, and model organisms in the genus have remained unclear. New collections of *C. variopedatus* and *C. pergamentaceus* from their type localities, recent collections of specimens from the Indo-Pacific, and examination of type specimens have allowed morphological and genetic assessment of most species names within the genus. Three genes: cytochrome oxidase subunit I, 28S ribosomal RNA, and 18S ribosomal RNA, were sequenced for 47 specimens, with additional sequences included from GenBank. Phylogenetic relationships were assessed using Bayesian and maximum-likelihood methods. Morphological and genetic data show that many previously synonymized species names should be resurrected, and the current taxonomy underestimates the species diversity. Genetic data shows that while some species are wide-ranging, the distributions of most species are much more restricted than previously thought.

75.4 MOORE, MP*; MARTIN, RA; Case Western Reserve University; *mpm116@case.edu*

Size structure of the intraguild predation community shapes the adaptive landscape of a larval dragonfly

Natural selection is driven by the environment, yet how different environments alter relationships between traits and fitness (i.e. adaptive landscapes) is rarely quantified. For instance, despite the importance of size-structured intraguild predation (IGP) interactions to population dynamics, their role in shaping adaptive landscapes is unknown. Greater size structure may elevate mortality via increased predation, promoting greater variance in fitness of the IG prey (i.e. differences in landscape elevational change). Shifts in size structure may also alter the relative importance of traits associated with escaping predation versus improved competitive ability (i.e. changes in adaptive peak location). Here, we assessed selection on 480 uniquely marked dragonfly larvae (*Pachydiplax longipennis*; IG prey) in experimental pools where we altered the size structure of the IGP community by manipulating the presence of an IG predator (*Anax junius*) and the degree of size variance within the IG prey (high/low). Variance in fitness was greater in pools with the IG predator. Directional selection favored larger head sizes and lower body condition but did not vary in strength or direction among environments. However, correlational selection varied between IG predator environments. In pools without IG predators, selection favored large larvae with moderate body condition and intermediately sized larvae with high body condition. In pools with IG predators, selection only favored large larvae with relatively low body condition. Overall, these results indicate that variation in the size structure of the IGP community, via the presence of a top IG predator, primarily altered the elevational change and the location of the adaptive peaks on the adaptive landscape.

24.3 MOORE, TY*; COOPER, KL; BIEWENER, AA; VASUDEVAN, R; Univ. of Michigan, Univ. of California, San Diego, Harvard Univ.; *taliaym@gmail.com*

How the biomechanics of ricochetal bipedalism enhances predator evasion, resource partitioning, and taxonomic diversity in desert rodent communities

Bipedal hopping in kangaroos is highly economical, enabling foraging over large areas; however, small bipedal rodents differ vastly in their biomechanics and ecology. We characterized the gait, dynamics, kinematics, and behavioral ecology of jerboas, small bipedal desert rodents. Jerboas are the only bipedal rodent with three gaits, which we found are not used in distinct speed ranges as would be expected for most terrestrial animals ($p=0.07$). Gaits are instead associated with distinct ranges of acceleration and deceleration ($p=0.02$), and jerboas frequently transition between gaits during short bouts of locomotion. Furthermore, we found that jerboa tendon elastic energy storage contributes only 6% of the energy required for a vertical leap, suggesting specialization for acceleration and maneuverability. By simulating predation under natural field conditions, we found that jerboas use their enhanced maneuverability to generate significantly less predictable trajectories than sympatric quadrupedal rodents, likely limiting a predator's ability to plot an intercept course. Therefore, jerboas should be able to forage in areas exposed to predation with less risk than sympatric quadrupeds. We tested this hypothesis by measuring open-field anxiety in field and lab conditions and found that jerboas spend over 300% more time in exposed areas than sympatric quadrupedal jirds ($p=0.00016$). The enhanced maneuverability and predator evasion ability conferred by ricochetal bipedalism therefore appears to underlie the distinct habitat preferences of sympatric rodent species, decreasing interspecific competition. Thus, evolutionary innovation in locomotor biomechanics helps to explain the surprisingly diverse rodent communities competing for limited desert resources.

138.4 MOORE, BC*; DOES, MD; KELLY, DA; Sewanee: The University of the South, Vanderbilt University, UMass Amherst; *Bcmoore@sewanee.edu*

3D Magnetic Resonance Imaging (MRI) to Investigate Crocodylian Phallic Functional Morphology

Animal phalluses use tissues with different material properties for a variety of functional roles, such as structural stiffness, tissue expansion, and gamete transport. These tissues can change shape and position relative to one another during reproductive function, and 3D modeling will improve our understanding of how they interact. Here, we present a model of the male adult American alligator (*Alligator mississippiensis*) phallus developed by combining 3D reconstructions of MRI image stacks with corresponding paraffin histological sections. Adult male alligator phalli collected at Lake Woodruff, Florida were fixative preserved, MRI-scanned intact after equilibrating in PBS, and then paraffin-sectioned and stained. Combining these techniques captured phallic anatomy with sufficient resolution to identify functional regions within the intact tissue: specifically the collagen-rich ridged shaft, the inflatable region of the distal glans, and the inflatable tissues defining the sperm-conducting ventral sulcus groove. MRI imaging also revealed collagen fiber bundle orientations, thus better explaining tissue-specific material properties associated with phallic function. These results demonstrate that this type of noninvasive imaging can facilitate investigation of tissue-specific material properties associated with phallic function by capturing internal morphology prior to histology or materials testing. It is applicable across the broad range of crocodylians. We hope to use this technique to understand phallic variation among crocodylians, identifying both conserved morphologies across species and species-specific phallic novelties, and to develop functional hypotheses incorporating the gross spatial relationships of reproductive tissues and their microanatomical and chemical characteristics.

118.6 MORAN, C/J*; RZUCIDLO, C/L; GERRY, S/P; Fairfield University; *cmoran.mlml@gmail.com*

Locomotor Physiology of a Hibernating Fish in the Family Labridae

Winter conditions in the North West Atlantic cause cunner *Tautogolabrus adspersus* to enter a state of extended torpor when water temperatures drop below 10° C. As one of the northern most species in the primarily tropical family, Labridae, this species has adopted a form of hibernation as a physiological response to low temperatures. We examined the impact of acclimation temperature (5, 10, 15, 20° C) on steady swimming in cunner. We hypothesized that maximum sustainable swimming speed and gait transition speed would increase with increasing temperature. Conversely, cost of transport and fin beat frequency at a given speed would not change across temperature. Through swimming step trials we found that maximum sustainable swimming speed and gait transition speed increased significantly with increasing temperature. Both cost of transport and pectoral fin beat frequency were highest at the warmest temperature tested. Low oxygen carrying capacity at high temperatures as well as an elevated standard metabolic rate were likely responsible for the increasing cost of transport with increasing temperature. At warmer (15 and 20° C) temperatures fish were capable of reaching higher velocities, causing the increase in pectoral fin beat frequency with increasing temperature. Low metabolic output and locomotor capabilities were observed at ≤ 10° C, supporting the observation of a behavioral shift at this temperature. Observations made in this study demonstrate the physiological cost of performance through an ecologically relevant temperature regime. Additionally, this work suggest that further warming in the North West Atlantic will increase the physiological cost of overwintering.

P1.200 MORAN, C/J*; ELLERBY, D/J; TRUEBLOOD, L/A; GERRY, S/P; Fairfield University, Wellesley College, La Sierra University; *cmoran.mlml@gmail.com*

Locomotor Muscle Kinematics and Physiology of Polyphenic Bluegill

Polyphenic bluegill sunfish *Lepomis macrochirus* differ in steady and unsteady swimming performance. Pelagic fish demonstrate a higher gate transition speed and lower cost of transport at that transition speed. Similarly, pelagic bluegill show a faster predator escape response. As a result, we hypothesized that pelagic bluegills would have a higher force output and maximum contraction velocity of pectoral, slow and fast myotomal muscles as compared to littoral bluegills. Additionally, given the greater swimming performance of pelagic fish, we hypothesized that they would have higher lactate dehydrogenase and citrate synthase activity when compared to littoral bluegills. To address these hypotheses, we measured maximum force, time to peak force and time to half relaxation for tetanic and twitch contractions. We also performed muscle slack-test protocols to estimate Vmax. For the enzyme analysis, we measured lactate dehydrogenase and citrate synthase activity in the pectoral and myotomal muscles. Generally, littoral and pelagic fish did not differ in their muscle kinematics. However, littoral fish had a higher slow myotomal muscle twitch and tetanic force than pelagic. This indicates that littoral red muscle produces more force, per unit area, than pelagic red muscle. The non-significant differences between ecomorphs suggest there is little variability in muscle mechanics. Pelagic bluegills had significantly higher levels of both lactate dehydrogenase and citrate synthase activity in the myotomal muscle, as predicted by their superior swimming performance. This result supports the observation that pelagic fish are better steady and burst swimmers than littoral fish. Pelagic bluegills occupy open water habitats and have a wide array of fish predators which are likely selective pressure on steady/burst swimming performance and enzyme composition.

S5.1 MOREAU, Corrie S.; Field Museum of Natural History; *cmoreau@fieldmuseum.org*

The Diversity and Function of Gut Bacteria in Herbivorous Ants

Although many insects engage in herbivory and likely rely on gut-associated bacteria to provision their diets, very few have been studied in detail. The ants provide an excellent system to study the diversity, distribution, and influence of gut-associated bacteria as herbivory has evolved many times (we can ask how diet influences associations), we have a well-resolved phylogeny for the group (to understand the role of shared evolutionary history or convergence), and ants are distributed around the world (permitting us to control for shared environment). Using next-generation sequencing we have found a diversity of bacteria associated with ants, with several key bacterial groups represented in herbivorous species, including Rhizobiales and Burkholderiales. Using the turtle ants, genus *Cephalotes*, we have several lines of indirect and direct evidence on the role these bacteria play in up-regulating their hosts diet. Specifically we find that some core gut bacteria are upregulated when turtle ants are feed diets that contain pollen, a food source very few organisms have been able to successfully leverage due to the heavily defended pollen cell wall. We also find the densest bacterial communities in the part of the ant digestive tract where the Malpighian tubules, which are responsible for excreting urea, come into contact with the digestive tract. Leveraging labeled nitrogen and antibiotic manipulations of the host to knock down/out their resident gut bacterial communities we demonstrate that the gut bacteria of the turtle ant provides essential amino acids to the host. In addition, using metagenome sequencing of the gut-associated bacteria we find the core bacteria from *Cephalotes* can synthesize essential amino acids.

10.1 MOREHOUSE, NI*; ZUREK, DB; TAYLOR, LA; CRONIN, T; University of Cincinnati, University of Florida, Gainesville, University of Maryland, Baltimore County; *nmorehouse@gmail.com*

Repeated Evolution of Color Vision Underlies Rapid Diversification of Salticid Male Coloration

A major goal of evolutionary biology is to understand the events that lead to rapid diversification of form in the living world. Major shifts in sensory function are likely to play an important role in the diversification of signals. We studied whether major transitions in color sensitivity underlie the rapid diversification of male courtship coloration in the Salticidae, or jumping spiders. In many species of jumping spiders, males perform elaborate courtship dances. Courting males often showcase colored body parts during these dances. In the majority of jumping spiders, these male visual signals are limited to a restricted color gamut, typically blues, greens, and browns. However, several jumping spider taxa depart from this trend by employing yellows, oranges, and reds. These jumping spiders present a conundrum, because data collected from closely related taxa suggest that their visual systems should have limited color discrimination abilities based on a system of UV-green dichromacy, and should therefore lack the ability to discriminate long wavelength colors such as yellows or reds. Here, we present evidence for two independent, functionally distinct evolutionary origins of color vision in the Salticidae: filter-based trichromacy in the colorful *Habronattus* jumping spiders of North and Central America, and non-filter-based tetrachromacy in the Australian "peacock" spiders of the genus *Maratus*. Using microspectrophotometry, histology, and visual system modeling, we characterize the sensitivities of these novel color vision systems and describe how they might have enabled the evolution of a wider gamut of male courtship coloration in these two spider groups.

131.5 MORISHIGE, K*; MORAN, AL; University of Hawai'i at Manoa; *kimmhkm@hawaii.edu*
Environmental drivers of variation in maternal investment of Colobocentrotus atratus across the Hawaiian Archipelago
Hawai'i's intertidal shorelines are extremely vulnerable to rising ocean temperatures, habitat degradation, and harvesting pressure. In response to these threats, there is a need to understand how reproductive success of resource species is affected by these and other environmental factors. In Hawai'i, there is sustained interest among local communities in developing sustainable management that incorporates reproductive and early life histories of resource invertebrates. This study investigates environmental factors that drive spatial and temporal variation in population densities, egg quality and larval fitness of a culturally and ecologically important Hawaiian species of sea urchin, *Colobocentrotus atratus*. Urchins were collected from a total of eight populations around O'ahu and Hawai'i Island in the spring and fall spawning seasons. Test diameter and height were recorded and egg volume and per-female fecundity were recorded. Test diameter had no significant effect on egg volume or fecundity across sites, suggesting that body size may not be a good indicator of reproductive output or an important factor in decision-making about regulated harvesting. There were significant differences in fecundity and egg volume between sites and season, as well as significant site-by-season interactions. These data suggest that maternal investment is affected by physical-biological factors on temporal and local scales, and we will investigate these factors by monitoring reproductive seasonality, population densities, algal cover, temperature, and algal nitrogen content at each site over three years. This project will shed light on the environmental drivers of variation in maternal investment and will facilitate sustainable management of Hawai'i's intertidal environment in the face of harvesting pressure and changing climate.

13.2 MORRIS, ZS*; PIERCE, SE; ABZHANOV, A; Museum of Comparative Zoology, Harvard University, Department of Life Sciences, Imperial College London ; *zmorris@fas.harvard.edu*
Craniofacial growth zones and modularity in Amniota: insight from the model crocodylian, Alligator mississippiensis.
Birds and crocodylians are each others closest living relatives and, with extinct groups like dinosaurs, form the clade Archosauria. The evolution of the bird skull and how birds develop differently from mammals is well studied, but less is known about crocodylian development. It is still unknown how cartilaginous growth zones in the cranium control the size and shape of the crocodylian face. In mammals, cartilaginous growth plates (synchondroses) in the cranial base expand and ossify the skull. In birds, a growth zone at the anterior end of the beaked face expands and likewise shapes the bones of the skull (apical growth). This apical growth may be unique to birds because of their specialized beak and unique patterning of the face. However, without data from crocodylians, it is possible that apical growth of the rostrum is a developmental feature of Archosauria. We studied the dynamics of cell proliferation in developing embryos of *Alligator mississippiensis* using *in ovo* injection of 5-ethynyl-20-deoxyuridine (EdU) at key developmental stages during snout morphogenesis. Identification of EdU-positive cells in medial sections of the developing face allowed us to characterize the pattern of facial growth in *A. mississippiensis*. During early stages growth was distributed throughout the rostrum and not constrained in an apical growth zone. Later stages with well defined cranial cartilages do not show concentrated growth zones within. This suggests crocodylians have a unique pattern of growth from either mammalian or avian models. Our study adds important data about amniote cranial growth patterns, which is key to understanding the evolution of facial morphogenesis.

112.7 MORRIS, JS*; RUFF, JS; POTTS, WK; CARRIER, DR; University of Utah; *j.s.morris@utah.edu*
Grappling with inefficiency: socially dominant male house mice have reduced locomotor economy
Economical locomotion and maintaining social dominance are vital to many speces because of their direct impact on components of fitness. Locomotor economy is thought to be an important performance trait because it directly influences total daily energetic expenditure. For example, reduced locomotor economy and the subsequent higher energetic demand may increase viability costs, such as increased foraging time and exposure to predation, as well as decreased free energy for growth, maintenance, and reproduction. Social dominance is important because it often directly determines reproductive success. In species that fight to determine social dominance, fighting performance may be under strong selection. However, traits that improve either fighting ability or locomotor economy may decrease performance in the other, resulting in a trade-off. We used populations of wild-derived house mice (*Mus musculus*) in 8-week social competition trials in semi-natural enclosures to directly measure several aspects of male reproductive fitness including social dominance through control of female-occupied territories. In addition, we measured locomotor economy for each male across a range of intermediate speeds using running trials in an enclosed treadmill and open-flow respirometry. Our results indicate that socially dominant male mice have a higher cost of transport (i.e., reduced locomotor economy) than non-dominant males. This relationship was significant for measurements taken both before and after social competition trials. In contrast to the positive correlation between body mass and social dominance in other species, body mass was not predictive of social dominance in our mice, indicating that other physiological, musculoskeletal, or behavioral traits underlie these performance differences. These results are consistent with the hypothesis that there is a trade-off between economical locomotion and fighting ability.

107.4 MOSELEY, DL*; DANNER, RM; DANNER, JE; PHILLIPS, J; DERRYBERRY, GE; LUTHER, DA; DERRYBERRY, EP; George Mason Univ., Tulane Univ., UNC Wilmington, Tulane Univ., George Mason Univ.; *dana.moseley@gmail.com*
Cultural selection as a mechanism of acoustic adaptation to city noise: a songbird chooses to copy less degraded songs
Cities are evolutionarily recent environments that impose novel selection pressures on organisms. Recent research in acoustic communication in urban contexts has found that birds change their vocalizations in the presence of human generated noise. An as of yet unexplored question asks, how do young birds learn songs in the face of urban noise? We explore how young males choose songs to copy and how these choices may drive cultural evolution and sexual selection in a behavioral model, white-crowned sparrows (Zonotrichia leucophrys). We test whether males preferentially copy songs less masked by city-like noise and the consequences of these decisions for the vocal performance of their learned songs. We find males copy less masked songs significantly more than songs masked more extremely by noise. Further the presence of noise appears to affect the complexity and vocal performance of their copied songs. These results suggest how cities may impact cultural selection, and we discuss the evolutionary implications of these findings for how birds cope acoustically in urban environments.

P3.125 MOSO, E/M*; ENZOR, L/A; HANKINS, C; BARRON, M/G; U.S. Environemtnal Protection Agency; *moso.elizabeth@epa.gov*

The Effects of Acidification and Hypoxia on the Estuarine Organisms Cyprinodon variegatus (Sheepshead Minnow) and Americamysis bahia (Mysid Shrimp)

The interactive and combined effects of coastal acidification and hypoxia on estuarine species is an increasing concern as these stressors change concomitantly. There is a need to understand how these environmental factors interact, as well as their effect on estuarine organisms. A method was developed for this research whereby four exposure treatments were created simultaneously: ambient, elevated $p\mathrm{CO_2}$, (~1300µatm, IPCC RCP 8.5 scenario), hypoxic (low dissolved oxygen, ~2 mg/L), and combined elevated $p\mathrm{CO_2}$ with low dissolved oxygen. An exposure with variant water quality parameters allows for the comparative study of organismal survival response to acidified and hypoxic conditions. The goal of this research is to determine acute species sensitivity, which is determined by survivability, to the combined effects of elevated $p\mathrm{CO_2}$ and hypoxia over a 5 day period, as well as possible differences in sensitivity between life-stages. Preliminary research on sheepshead minnow and mysid shrimp, indicates that mysid shrimp were tolerant of both elevated $p\mathrm{CO_2}$ and low DO exposure regardless of life-stage, whereas sheepshead minnows were more sensitive to the combined effects of acidification and hypoxia.

58.3 MOSS, ND*; MASLAKOVA, SA; Oregon Institute of Marine Biology, University of Oregon; *nmoss3@uoregon.edu*

Regeneration in the pilidium

Ability to regenerate is found in many groups of metazoans but the majority of research is focused on adults from just a few taxa, such as planarians and hydra. Increasing the diversity of study organisms and life stages can reveal new and interesting aspects of regeneration mechanisms. Studying regeneration in invertebrate larvae can simultaneously track cell migration and proliferation while observing the regeneration of structures and restoration of function at the organismal level. Injury for long lived planktonic larvae is likely, and therefore tissue reorganization and regeneration is expected, but very few types of marine invertebrate larvae have been surveyed for their ability to regenerate. Here we present the results of regeneration assays on the nemertean pilidium larva. The nemertean pilidium larva spends weeks to months in the plankton, during which time the juvenile worm forms inside from a series of initially isolated rudiments. The fully grown juvenile erupts from the larval body in a catastrophic metamorphosis, and many juveniles consume their larval body. As the juvenile is formed, the larval body continues to grow aided by the putative stem cells. These putative stem cells could contribute to the maintenance and successful regeneration of the larval body, but direct evidence of this is lacking. We document the capacity and timeline for regeneration after surgical removal of the larval apical organ or lappets, and use BrdU assays to test hypotheses about contribution of the larval stem cells to regenerating structures.

S10.11 MOUSTAKAS-VERHO, JE*; ZIMM, R; BENTLEY, B; WYNEKEN, J; Institute of Biotechnology, University of Helsinki, University of Western Australia, Florida Atlantic University; *Jacqueline.Moustakas@helsinki.fi*

Evolutionary innovations and developmental experiments in organs of skin

The origin of the turtle shell over 200 million years ago greatly modified the amniote body plan, and the morphological plasticity of the shell has promoted the adaptive radiation of turtles. The shell is a layered structure formed by basal endochondral axial skeletal elements (ribs, vertebrae) and plates of bone, which are overlain by keratinous ectodermal scutes. Scutes develop as ectodermal appendages from placodal signaling centers and are patterned by reaction-diffusion dynamics. These placodal signaling centers are hypothesized to be developmental modules that are responsible for the evolutionary plasticity and diversification of the turtle shell's scute patterns. A computational model shows how two coupled reaction-diffusion systems reproduce both natural and abnormal variation in turtle scutes, and hypothesizes that scute anomalies are epigenetic and may be a consequence of environmental conditions during incubation. Corroborating this hypothesis is evidence from natural nests of cheloniid sea turtles that were incubated under natural conditions, but during normal and hotter-than normal years. We observe that scute anomalies increase greatly in hot conditions and increase further with drought. We further examine scute variation by systematically introducing different perturbations of different magnitudes and at different stages into in silico scute development, thereby characterizing and quantifying the variation generated epigenetically over development. This way, we draw a variational morphospace that might provide insight into the developmental origin of phenotypic variation.

1.1 MOUSTAKAS-VERHO, JE*; STENBERG, OE; ANTTILA, J; JERNVALL, J; Institute of Biotechnology, University of Helsinki, Integrative Ecology Unit, University of Helsinki; *Jacqueline.Moustakas@helsinki.fi*

Is high complexity unbearable?

Bears are an ecomorphologically diverse clade and their dentition reflect the wide range of dietary habits, from the hypercarnivorous polar bear, omnivorous sloth, sun, black, and brown bears to the herbivorous panda bear. The shape of the mammalian dentition is determined prior to eruption and modified only by wear. The complexity of the dentition has been shown to correlate with diet, and we have used this metric to reconstruct the diet of the European cave bear, *Ursus spelaeus*, a member of the Pleistocene megafauna that went extinct during the Last Glacial Maximum. The teeth of the cave bear exhibit the greatest complexity of all bear species, even higher than panda bears, which are specialized bamboo feeders. This suggests that the dentition of cave bears was highly specialized for a vegetation diet, and may not have been sustainable with changing climates and landscapes. An alternative hypothesis that we investigate is that the cave bear became developmentally unstable and ended up in a complexity trap, unable to further produce adaptive change. We contrast this with the simpler dentition of the polar bear, a population currently experiencing habitat fragmentation.

21.3 MOWERY, MA*; PAKIRATHAN, R; MASON, AC; ANDRADE, MCB; University of Toronto Scarborough; *monica.mowery@mail.utoronto.ca*
Development and Behavioural Variation in the Redback Spider
Behavioural plasticity can increase individual fitness in the face of environmental changes. Nevertheless, correlated suites of behavioural traits (behavioural syndromes) can also be advantageous and these necessarily reduce plasticity. Here we measured a suite of behavioural traits in Australian redback spiders, *Latrodectus hasselti*, to determine (1) whether behavioural syndromes were present, (2) whether syndromes were plastic as a function of variation in diet (well-fed or unfed), and (3) whether variation in diet and behavioural traits of females was linked to offspring development, behaviour and fitness correlates (sibling cannibalism, size, longevity). Measured behavioural traits included latency to attack prey (voracity), boldness, latency to mate, and resting metabolic rate, in addition to web and body size in nature. We found that spiders showed repeatable voracity and boldness, and that individuals that attacked prey faster were also bolder. Unfed females were quicker to attack prey and bolder than well-fed females. We found transgenerational effects of maternal diet on offspring cannibalism rates, development, and behaviours. Offspring of fed females cannibalized more of their siblings than offspring of unfed females. Survivors of the cannibalism treatment were bolder and built webs faster than control individuals, and were also larger, developed faster, and survived to later instars. We conclude that Australian redback spiders have repeatable individual differences in behaviour along a boldness-aggression axis. Despite this syndrome, environmental variation can change behavioural correlations, and have physiological and behavioural effects that are apparently transmitted across generations.

27.6 MUECK, K; Univ. of Louisiana at Lafayette; *kristy.mueck@yahoo.com*
Aestivation in the apple snail Pomacea maculata
The apple snail *Pomacea maculata* is a nuisance invasive with the potential to become an ecological and agricultural threat in the southeastern United States. To gain insight into the ability of the snails to survive in intermittent bodies of water, such as rice fields, the survival of the animals while exposed to air was studied. Apple snails (*Pomacea maculata*) were collected from local bayous during the spring and summer months and subsequently weighed and tagged. Snails were fed lettuce and maintained in large, indoor, temperature controlled aquaria. Eight snails were then randomly selected, weighed, and placed in individual Petri dishes to induce aestivation. Snails were maintained at room temperature and a humidity between 60%-70%. They were weighed daily for three months, then weekly for the remainder of the experiment. Weight was calculated as a percentage of the weight on day one of the experiment, due to variation in the onset of aestivation among individual snails. Fifty percent of the snails survived 307 days while maintaining 70% of their body mass. Upon re-immersion in water, the surviving snails became active within 24 hr. There was no additional mortality. These results suggest that de-watering rice fields may not deter establishment of apple snails.

P1.8 MULLER, UK*; MERANA, G; BOSSE, E; LENT, DD; WALTER, EM; California State University Fresno; *umuller@csufresno.edu*
Exploring student understanding and attitudes in introductory biology courses: lessons learned
Biology university instructors received their call to action in 2011 in the form of AAAS' Vision and Change report, which identifies core concepts and competencies. In the Biology Department at California State University Fresno we have begun to implement Vision and Change as part of a college-wide faculty-development initiative aimed at improving student success in introductory STEM courses. We used validated concept inventories and attitude surveys as pre-post tests to quantify changes in conceptual understanding and attitudes during our two introductory biology courses. We found significant decreases in certain categories of the CLASS attitude results (Colorado Learning Attitudes about Science Survey), such as real-world relevance, despite significant increases in conceptual understanding (Energy and Matter in Dynamic Systems survey; Conceptual Inventory of Natural Selection; Measure of Understanding of Macroevolution). We saw significant increases on certain knowledge items, but overall pre-post scores were not significantly different. We also found that our course currently serves Biology majors, but not non-Biology major students taking our introductory courses to fulfill general-education requirements. We plan to intensify of effort to observe instructors in their classroom (using COPUS - Classroom Observation Protocol for Undergraduate STEM) and conduct interviews with students to better understand the causes of the observed trends and to develop pedagogical strategies that reach non-Biology majors and improve also attitudes, not just conceptual understanding.

103.2 MUNGUIA, P; BACKWELL, P; DARNELL, MZ*; The University of Adelaide, The Australian National University, The University of Southern Mississippi; *zachary.darnell@usm.edu*
Thermal constraints on microhabitat selection and mating opportunities in fiddler crabs.
Hot tropical environments constrain ectotherm mating opportunities when mate selection occurs on the surface. Thus, microhabitats and refugia can become a qualitative trait in mate selection. In fiddler crabs, the enlarged claw of males can act as a heat sink, which becomes advantageous when surface temperatures reach 50°C during the day and crabs are actively seeking to mate. *Uca mjoebergi* females prefer male burrows found in the shade, therefore we asked what are the thermal constraints imposed on males and females in shaded and non-shaded habitats. Crab surface activity decreases and body temperature increases as the day progresses, with more crabs active in shaded microhabitats than in sunny microhabitats. Body temperature was lower in male crabs found in burrows relative to crabs on the surface. Male claw size explained 10% of body temperature. Results suggest thermal constraints imposed on males can be overcome by the large claw acting as a heat sink and the burrow acting as a refuge from heat. Classic sexually selected traits, including ornaments and behaviors, can have a secondary purpose in thermoregulation.

29.1 MUNOZ, MM*; ANDERSON, PSL; PATEK, SN; MUNOZ, Martha; Duke University, University of Illinois, Urbana-Champaign; *martha.munoz@gmail.com*

Mantis shrimp reveal the evolutionary dynamics of mechanical sensitivity in form-function relationships.

The relationship between structure and function impacts the evolutionary dynamics of phenotypic diversification. Biophysical relationships are thus expected to influence rates of morphological evolution, but this has rarely been tested. Here we test the hypothesis that mechanical sensitivity - the sensitivity of mechanical output to variation in its underlying components - correlates with rates of morphological evolution in the four-bar linkage system of mantis shrimp. Mantis shrimp (Order: Stomatopoda) are crustaceans that possess a specialized raptorial appendage used to harpoon elusive prey or bludgeon hard-shelled prey. The four-bar linkage system in the raptorial appendage transmits stored elastic energy to the kinetic energy of the appendage. We compared evolutionary rates among the morphological components (links) of the four-bar linkage system and their mechanical output (kinematic transmission, KT). Using a likelihood-based phylogenetic approach, we found that rates of morphological evolution correlate positively with mechanical sensitivity, suggesting a connection between biophysical relationships and evolutionary dynamics. We then examined the connection between mechanical sensitivity and trait-dependent diversification between two types of mantis shrimp ("spearers" and "smashers"). Although the rate of evolution and strength of selection varied between smashers and spearers, mechanical sensitivity did not appear to impact these patterns. The connection between mechanical sensitivity and evolution provides a window into the interaction between physical rules and evolutionary diversification. We discuss how our results influence our understanding of evolutionary patterns of diversity, such as many-to-one mapping.

P1.69 MUNSTERMANN, M/J*; ROCHA, L/A; ROCHA, C/R; Univ. of Connecticut, Storrs, Calif. Acad. Sciences, San Francisco; *maya.munstermann@uconn.edu*

Reef Pest or Ecosystem Destroyer? The Diet of an Invasive Species in the Caribbean, the Lionfish Pterois volitans

Pterois volitans, the lionfish, is a scorpaenid native to the Indo-Pacific Ocean. In Caribbean reefs, it has become an invasive species with a depth range from 1 to 1,000 feet. *P. volitans* is a threat due to their immense numbers and prodigious consumption of prey at all depths of the Caribbean reefs. *P. volitans* in the Caribbean are shown to be opportunistic feeders, consuming almost all available prey in the surrounding environment. Past studies have investigated the impact of *P. volitans*' dietary preferences in shallow reef ecosystems. The current study, however, explored the same impact in mesophotic ("twilight zone") reef ecosystems in two localities. Twenty-seven specimens of *P. volitans* were sampled from mesophotic reefs (200-400 feet) near Curaçao and 21 from the mesophotic reefs near Bermuda. The entire contents of each specimens' stomach were removed, DNA extracted and the DNA sequenced for each sample. From the DNA matches provided by GenBank, we identified 7 orders, 26 families, and 30 species of fish and crustaceans. The dietary analysis of *P. volitans* from shallow water differed from that of the species in mesophotic depths. In shallow reefs, Labridae was the most consumed family of fish (27%). In mesophotic reefs, the Serranidae (67%) was the most strongly represented fish family in the stomach content analysis. *Paranthias furcifer* made up 94% of serranid sequences, revealing a high consumption rate for this species by *P. volitans*. It is now suspected that *P. furcifer* populations face endangerment due to the high levels of *P. volitans* predation.

P1.171 MURILLO, A*; BOREHAM, D; WILSON, J; SOMERS, C; MANZON , R; Univ. of Regina, Northern Ontario School of Medicine, McMaster University; *amurillo4401@gmail.com*

The Heat Shock Response of Round Whitefish

Thermal stress can be a consequence of a fish's natural environment or a result of anthropogenic activities such as industrial thermal pollution. The production of heat shock proteins (hsp) is an important and highly conserved cellular response to thermal and other stressors. In this study, we assessed the kinetics of the heat shock response by quantifying changes in gene expression of hsp90α, hsp70, hsp47, hsp90β, and heat shock cognate 70 (hsc70) in embryonic and young of the year (YOY) juvenile Round Whitefish (*Prosopium cylindraceum*; RWF). RWF embryos and YOY juveniles were subjected to two different heat shock temperatures (+6 and +9° C) for 1 to 4 h. Embryo and YOY RWF were allowed to recover at control temperatures for 0 to 48 h prior to sampling and quantifying hsp mRNA levels using RT-qPCR. Of the 3 typically inducible hsps, only hsp70 was increased in embryos following heat shock. By comparison, both hsp70 and hsp47 increased in YOY juveniles. mRNA levels of the inducible hsp90α, the constitutive hsp90β, and hsc70 did not vary significant in comparison to controls. Data on recovery from heat shock and on the ontogeny of the heat shock in RWF embryos will also be presented and discussed in the context of RWF being exposed to developing in industrial thermal effluents. A better understanding of the impact of thermal fluctuations which can arise from thermal effluents or climate change on key life history stages of a sensitive cold water species may aid in predicting and mediating anthropogenic influences on these and other near shore spawning fishes.

77.4 MURPHY, R; BISHOP, CD*; St, Francis Xavier University, Antigonish, NS, Canada; *cbishop@stfx.ca*

Acquisition of Green Algal Symbionts in Egg Masses of the Northeastern Yellow Spotted Salamander: Horizontal or Vertical Transmission, Neither or Both?

All descriptions of symbioses require explanations about the acquisition of symbionts by the host. The discovery that unicellular green algal symbionts of egg masses of the northeastern yellow spotted salamander *Ambystoma maculatum* invade embryonic tissues and cells raised the possibility of vertical transmission as a mode of symbiont acquisition. Previous work also identified the free-living alga *Oophila amblystomatis* in *A. maculatum* breeding habitat, but no definitive tests have distinguished among modes of symbiont acquisition. We tested the mode of acquisition of *O. amblystomatis* in *A. maculatum* egg masses by collecting adult female salamanders from the wild during annual spring reproduction. Animals were held in pond water that was either untreated, treated with UV filters or autoclaved. The growth of algal cells in treated and control egg masses was monitored microscopically and quantified. Lower rates of algal growth were observed in egg masses treated with either UV filtered or autoclaved water, indicating that algae invade egg masses horizontally from pond water. However, in some cases of egg masses incubated in autoclaved water, algal growth was observed, raising the possibility that both horizontal and vertical modes of transmission are present. There remains an additional possible mode of acquisition: female salamanders fertilize themselves by collecting spermatophores. Therefore, evidence of "vertical transmission" may be from the spermatophore proper, or from algae accumulating on the surface of spermatophores during their period of exposure to pond water. Future tests will be designed to distinguish among these various modes of acquisition, and how they might vary among ponds and years.

P2.164 MURPHY, C.T.*; MARTIN, C.; FRENCH, A.N; BELTRAN, R.S.; BURNS, J.M.; LAPSERITIS, J.M.; 1. Naval Undersea Warfare Center, Division Newport, 2. Department of Biological Sciences, University of Alaska Anchorage; *christin.murphy@navy.mil*

Interspecies Variability in Pinniped Vibrissal Morphology and Array Architecture

Seals use their specialized vibrissae to track hydrodynamic trails and find their prey. This ability has generated considerable attention in engineering research and inspired attempts to create biomimetic artificial sensors. Understanding the structure and function of the biological system is crucial to these efforts. Due to sample availability and substantial behavioral data on its hydrodynamic tracking abilities, the harbor seal is often used as a model species to characterize the vibrissal system in pinnipeds. However, it is important to note that considerable variation in vibrissal surface morphology, number and distribution of vibrissae, and overall array architecture exists between species. We suspect that this variation is linked to foraging specialization, and we present methodologies for feature comparison at the vibrissal and array levels. An analysis of intra-array nearest-neighbor distances is explored to quantify array spacing, using photogrammetric techniques to standardize inter-array comparisons. This method is validated against direct measurements on necropsy specimens and used to generate comparative mystacial bed maps of five phocid species, using field and laboratory photographic data. CT scanning of individual vibrissae with an enhanced contrast staining technique is used to generate 3D surface models of vibrissae for comparison of surface morphology. The assessment of morphological features using phylogenetic matrices will establish a basis for comparing vibrissal structure to foraging specialization across species.

144.3 MURPHY, MA*; SCHUL, J; Salisbury University, University of Missouri; *mamurphy@salisbury.edu*

Why Mate with Leaders? Direct Benefits Associated with Leader Preference in the Katydid Neoconocephalus ensiger

Leader preference, a female mating preference for males producing their calls ahead of their neighbors, is common in acoustically communicating insects and anurans. While this preference is taxonomically widespread and well-studied, the evolutionary origins remain unclear. We tested whether females gain a fitness benefit by mating with leading males in the katydid *Neoconocephalus ensiger*. We mated leading and following males with random females and measured the number and quality of F1, the number of F¬2, and the heritability of the producing leading calls. Females mated with leaders and followers did not differ in the number of F1 or F2 produced. However, females mated with leading males produced larger offspring than those mating with following males, suggesting a benefit of mating with leading males. We found no evidence that the male trait, the ability to produce leading calls, was heritable. This suggests that there is no genetic correlate for leadership ability and that the fitness benefit gained by females must be a direct benefit, potentially mediated by seminal proteins. The presence of benefits indicates that leader preference is selected for in *N. ensiger*, which may explain the evolutionary origin of leader preference in *N. ensiger*. Because the ability to produce leading calls was not heritable, leader preference will not become coupled with or lead to the exaggeration of this trait. This also prevents females from gaining a ‘sexy-sons' benefit, weakening the overall selection for leader preference.

P1.53 MURPHY, MJ*; HUNTER, KL; TAYLOR, RC; Salisbury University; *mmurphy9@gulls.salisbury.edu*

Your Lips Move But I Can't Hear What You're Saying: Cognitive Overload Disrupts Multimodal Mate Choice

Multimodality - the transmission of a signal through multiple sensory channels - is nearly ubiquitous in the animal kingdom. One hypothesized origin of multimodality is an adaptation to noisy signalling environments, in which one sensory channel compensates for interference in a second channel. Many species appear to use visual cues to improve acoustic discrimination in noisy environments, allowing them to focus on an individual signaler. Acoustic communication has been extensively studied in green treefrogs (*Hyla cinerea*). Like most other anurans, male acoustic signals are physiologically coupled to the inflation of the frogs' vocal sac. Prior research showed that females prefer male acoustic signals accompanied by the visual cue of an inflating vocal sac (robofrog). We hypothesized that multimodal signal evaluation may enhance females' ability to detect an attractive mate under acoustically complex (chorus-like) conditions. We exposed to wild-caught female green treefrogs (GTFs) to a combination of three unattractive signals; an attractive signal; and either a robofrog, band-filtered noise, or both the robofrog and the noise. We found that female GTFs were able to detect the attractive speaker in the presence of the four signals or in combination with the robofrog. However, when the masking noise was present, females chose the correct speaker no more often than would occur by random chance. Interestingly, the addition of the robofrog to the signal + noise complex did not improve females' ability to choose the attractive speaker. As the experiment was designed to mimic the conditions GTFs encounter under normal chorus conditions, the results suggest that the integration of multimodal cues may increase sensory (cognitive) loading and reduce discrimination in noisy environments.

P3.94 MURPHY, MA*; THOMPSON, NL; SCHUL, J; Salisbury University, United States Geological Survey, University of Missouri; *mamurphy@salisbury.edu*

Acoustic Synchrony at Fast Rates: A Unique Mechanism in the Katydid, Neoconocephalus ensiger

Males of many acoustically communicating insects synchronize their calls with those of neighboring conspecifics. In most species, males either advance or delay the timing of individual signals in response to a single stimulus pulse, whether the signal of a neighbor or an artificial stimulus. The pulse rate (10-14 Hz) of *Neoconocephalus ensiger* males is considerably faster than the rate of synchronized signals in other insect species (0.5-3 Hz). We found that they make no timing adjustments in response to single stimuli pulses. During interactions with conspecifics, males made only small adjustments to their pulse period in a single cycle. Large-scale timing adjustments only occurred in response to large delays between males. When entrained to a stimulus with a faster pulse period, males briefly interrupted calling; they resumed calling largely synchronized with the stimulus. Throughout the stimulus, males made gradual changes to their pulse period, similar to those observed during pair calling. After the stimulus ended, pulse periods increased over several minutes, but did not return to their pre-stimulus values. Thus social context influenced pulse period in *N. ensiger*. These results indicate that *N. ensiger* males synchronize calls by adjusting their intrinsic pulse period, resulting in the long-term effects, while all other synchronizing insects described adjust the timing of individual pulses then continue to call at their previous period immediately after. This unique mechanism may be a necessity because of neurological processing times and the scale of timing adjustments that can be made within a single *N. ensiger* pulse cycle.

P1.77 MURRELL, EM*; LEMMON, ME; RAY, S; KAYE, JP; Penn State University; *egmurrell@gmail.com*
Legacy effects of preceding cover crop species on mycorrhizae, nutrients, and plant-insect interactions in a cash crop
Arbuscular mycorrhizal fungi (AMF) are known to facilitate nutrient uptake and increase production of chemical defenses in plants, both which can improve plants' ability to resist insect herbivory. Cover crops - non-commercial species planted in between cash crops in a crop rotation - can naturally alter both soil nutrients and AMF communities. We tested whether different cover crop species could alter AMF colonization, plant chemistry, and plant-insect interactions in a proceeding cash crop. Cover crop species were either non-mycorrhizal, non-leguminous (canola, forage radish), mycorrhizal non-leguminous (cereal rye, oats), mycorrhizal leguminous (clover, pea), or absent (fallow). We measured the cascading consequences of each treatment on AMF colonization, cash plant (field corn) performance and an herbivorous insect (European corn borer) feeding on the plants. Plant N was higher in corn proceeding leguminous cover crops (pea and clover) than non-leguminous cover crops. Corn root AMF colonization was greater in plots previously planted with mycorrhizal cover crops than non-mycorrhizal or no cover crops. AMF colonization was strongly linked to plant P, and plant N:P ratio was predictive of corn plant height. Insect survivorship significantly differed among cover crop treatments, being highest on corn planted after a radish cover crop. Preliminary quantitative real time PCR (qRT-PCR) showed that constitutive levels of maize protease inhibitor (MPI) transcript in corn plants were marginally correlated with plant phosphorus and with European corn borer survivorship. Our data show that cover crops have indirect consequences on corn pest performance, via the pathways of altering AMF colonization, nutrient uptake, and chemical defense production in the cash crop.

P1.156 MUSAITIF, DZ*; JOST, JA; Bradley University; *dmusaitif@mail.bradley.edu*
Investigating the cellular and molecular response of the zebra mussel, Dreissena polymorpha , to acute and chronic cold stress and its implications on thermal tolerance
For sessile ectotherms, fluctuations in environmental temperature are unavoidable. Yet, these changes can have deleterious effects, often resulting in reduced performance or survival for these species. For the invasive zebra mussel (*Dreissena polymorpha*), little is known about their thermal physiology on a cellular level. Furthermore, the majority of studies have focused on high temperature stress, even though these animals spend several months each year exposed to cold water temperatures. A recent study showed a significant increase in the activity levels of a stress protein, AMP-activated protein kinase (AMPK) during exposure to cold, but biologically relevant, water temperatures. These results were consistent for animals collected over multiple seasons and for experiments ranging from hours to weeks of cold exposure. Since AMPK activity reflects changes in metabolic processes, these results suggest cold exposure increases energy demands. However, the underlying physiological changes and cellular mechanisms are poorly understood. One possible explanation is that the processes associated with seasonal thermal acclimation, which can involve changes in biochemical reaction rates and gene expression, may be stressful. Another possible explanation is that exposure to cold water temperatures results in cellular damage, therefore increasing the metabolic demands necessary for repair. The aim of this project is to investigate this response further by (a) determining the duration of exposure necessary to elicit an increase in AMPK activity, (b) the duration of increased AMPK activity levels, (c) whether this response results in altered thermal tolerances, and (d) to measure additional cellular and molecular parameters in order to determine whether this response is associated with cellular damage.

121.6 MYDLARZ, LD*; FUESS, LE; PINZON, JC; WEIL, E; University of Texas Arlington, University of Texas Southwestern Medical School, University of Puerto Rico; *mydlarz@uta.edu*
Disease Resistant Corals Activate Autophagy over Apoptosis after an Immune Challenge
Not all coral species are affected by disease equally. Some species are host to different diseases, but seem to successfully fight them reducing mortality. Other species are disproportionately infected on any given reef and experience high mortality due to disease. We are interested in the role immunity can play in directing these patterns and are evaluating coral immunity using several novel approaches. We exposed 4 species of coral that range in disease susceptibility, *Orbicella faveolata*, *Pseudodiploria strigosa*, *Porites porites* and *Porites astreoides*, to the immune stimulator, LPS and quantified the changes using full transcriptome sequencing. Using Ingenuity Pathway Analysis to analyze gene expression, we identified several pathways that correlated to coral resistance. For example, disease susceptible species up-regulated many genes in apoptotic pathways while disease resistance inactivated or suppressed these pathways. Moreover, disease resistant corals upregulated pathways involved in autophagy, indicating attempts at adapting to changing conditions. These data show how cell survival pathways contribute to the immune response and subsequent patterns of disease resistance on coral reefs. Understanding these mechanisms will help inform trajectories of reefs under continuous climate and disease pressure.

75.6 NADELL, CD*; RICAURTE, D; DRESCHER, K; WINGREEN, NS; BASSLER, BL; Max Planck Institute of Terrestrial Microbiology, Princeton University; *cnadell@gmail.com*
Bacterial fortresses: the biofilm matrix and microbial community assembly
Bacteria are highly social organisms that produce surface-bound communities, termed biofilms, which are embedded in a secreted matrix of extracellular polymers. The matrix is well known to confer protection from physical forces and other threats, but its role in the dynamics of community assembly is just being uncovered. To shed light on this problem I have developed an experimental system using the pathogen *Vibrio cholerae*, for which biofilm formation is essential to environmental survival and pathogenesis in human hosts. Here I will present a collection of findings on how the extracellular matrix influences competition for space and resources within biofilms, and how the matrix controls the community assembly of biofilms as they develop from single cells to complex multicellular populations. The results have implications for the evolution of pathogenesis, bacterial cooperation and competition, as well the the nature of ecological succession within microbial communities.

100.7 NADLER, JH*; BECKERT, M; Georgia Tech Research Institute; *jason.nadler@gtri.gatech.edu*

Attachment Mechanics of Diving Beetle Foreleg Palettes

The foreleg palettes of male diving beetles, *Dytiscidae*, have been studied for their ability to generate attachment forces up to four times their body weight through an array of attachment features on the protarsal palette that include two large suction-cup-like setae (0.2 to 1mm) and hundreds of smaller setae (20 to 50 µm). Though previous measurements indicate that most of the attachment strength is attributed to by the large setae, it has been suggested that the smaller setae improve attachment to rough surfaces. In this work, structural analyses of both the large and small, suction-based setae are presented. These analyses include the nanometer scale interfacial morphology, particularly on small setae. In addition, local mechanical properties are measured to inform a numerical attachment model. Results are used to support the design of engineered patterned surfaces with unique adhesion properties.

102.1 NAKAMURA, T*; GEHRKE, AR; LEMBERG, J; SZYMASZEK, J; SHUBIN, NH; Univ. of Chicago, IL; *tetsuya@uchicago.edu*

Digits and fin rays share common developmental histories

Comparisons of fish fins with tetrapod limbs have been limited by a relative lack of understanding of the cellular and molecular processes underlying the development of the fin skeleton. For example, knockout and cell lineage data of genes essential for patterning skeletal structures in mice have been lacking for orthologous genes in fish. Here, we provide the first functional analysis, using CRISPR/Cas9 and fate mapping, of 5' *hox* genes and enhancers in zebrafish that are indispensable for the development of the segments of endochondral bones of tetrapod limbs. We show that the fates of cells marked by the activity of an autodial *hoxa13* enhancer exclusively form elements of the fin fold including the osteoblasts of the dermal rays. Moreover, in *hox13* knockout fish, we find a dramatic reduction and loss of fin rays that is associated with an increased number of endochondral distal radials. Our data reveal a developmental connection between the fin rays and digits of tetrapods, and suggest a mechanism of endochondral expansion in tetrapod origins by via the transition of distal cellular fates.

P3.115 NAMBU, WR*; RIEUCAU, G; PORTER, ME; KAJIURA, SM; Florida Atlantic University, Boca Raton, Florida International University, North Miami; *kajiura@fau.edu*

Quantification of shoaling tendency and context-dependent collective behavior of blacktip sharks (Carcharhinus limbatus) during seasonal aggregations in Southeast Florida

Schooling in marine fishes is a strategy that can facilitate migration, enhance prey detection, provide safety benefits, or hydrodynamic advantages. Many schooling species make acute and rapid structural and behavioral adjustments in a highly coordinated manner, supporting the idea that schools can display a high degree of plasticity. Studying collective dynamics of free-ranging marine organisms remains challenging since it requires the development of non-intrusive observation methods to monitor and quantify social patterns. Despite recent studies of blacktip shark (*Carcharhinus limbatus*) migration patterns, little is known about the behavioral mechanisms that underlie their massive aggregations and their functions. We hypothesized that shoal-level modifications and context-dependent collective responses reflect changes in the way individuals balance their fitness tradeoffs. We developed a semi-automatized tracking algorithm to quantify *C. limbatus* abundance and shoaling dynamics (inter-individual distances and alignment level). We analyzed images collected during aerial surveys over six years, to link the behavioral measurements with biotic and abiotic factors. Ultimately, adaptive behavioral changes at the collective level have the potential to inform us about the effects of global environmental patterns on population dynamics and migratory patterns of gregarious shark species; information of prime importance for the development of sound conservation and management.

S11.7 NARENDRA, A*; KAMHI, JF; SHEEHAN, Z; Macquarie University, Sydney; *ajay.narendra@mq.edu.au*

Behavioural and neural adaptations in ants for navigating in dim light

The phenomenon of niche differentiation has long been considered the basis for coexistence of competitors and as reflecting the way in which animals avoid predation. While habitat and food-type partitioning are common, avoiding competition and predation by restricting activities to specific times of day were thought to be rare. However recent findings in a number of animal communities suggest temporal niche partitioning to be more common than previously recognized. Given the differences in ambient light intensity between day and night, it would appear that diurnal and nocturnal species require very different physiological adaptations to occupy their respective niches. To understand these adaptations, one requires a benchmark information processing task. One such task that is comparable across animals is visual navigation that scales from a few centimeters to several kilometers. Using this task allows us to identify the behavioural and neural adaptations that animals have evolved to be active in dim light and to also pinpoint the 'information processing cost' to be paid for occupying discrete temporal niches. Here we will focus on the ants, since (a) they allow us to record with high precision the navigational decisions and errors they make along their entire journeys under natural conditions and (b) they offer an opportunity to identify the evolution of sensory structures for discrete temporal niches not only between species but also within a single species. We will discuss the current state of knowledge on the external visual sensory arrays and adaptations in the higher order visual information processing centers that allows both diurnal and nocturnal ants to navigate in their respective visual environments.

93.5 NASH, C.S.*; HENDON, J.M.; DALY-ENGEL, T.S.; University of West Florida, Pensacola, FL, USA, Center for Fisheries Research and Development, Gulf Coast Research Laboratory, The University of Southern Mississippi, Ocean Springs, MS, USA; *csn9@students.uwf.edu*

The impact of varying reproductive periodicity on frequency of multiple paternity in the finetooth shark, Carcharhinus isodon

It has recently become apparent that polyandry - females mating with multiple males in one breeding season - is prevalent among the elasmobranchs (sharks, skates, and rays). This often leads to multiple paternity, or individual broods being sired by multiple males. As opposed to the clear advantages of polygynous mating to the male, the adaptive advantage of polyandry to the female or her brood is not clear. Some theories include female bet-hedging, trading up, or increased genetic diversity in the overall population. Alternatively, because injuries to the female are probable during mating events, it may simply be safer for her not to resist - a theory known as convenience polyandry. We are using polymorphic microsatellite markers to determine the frequency of multiple paternity in a small coastal shark of the Northern Gulf of Mexico (GoM), the finetooth shark (*Carcharhinus isodon*). This species has shown evidence of co-occurring annual and biennial reproductive periodicity in the Northern GoM population. We will compare the frequency of multiple paternity between these two subsets in order to determine if the rate is impacted significantly by long-term sperm storage and/or mate encounter rate. This will be the first study of its kind on *C. isodon*, allowing for comparison to other Carcharhinids to help determine how life history characteristics can impact mating behavior. This information is essential for forming effective management plans for species that are impacted by human activity.

P1.99 NATI, M*; ESCOBAR, L; SCHREIBER, AM; St Lawrence University, NY; *aschreiber@stlawu.edu*

Influence of Sonic Hedgehog Signaling on Intestinal Remodeling during Xenopus laevis Metamorphosis

The Xenopus intestine remodels during metamorphosis as the herbivorous tadpole transforms into a carnivorous frog. This remodeling includes thickening of the mesenchyme and smooth muscle layers, and folding of the epithelium. Virtually all metamorphic changes are mediated by thyroid hormone (TH) and its receptors that function as gene transcription factors. We have previously shown that when the intestinal epithelium is specifically prevented from responding to TH, this inhibits thickening of the intestinal walls and prevents epithelial folding, suggesting that one or more TH-responsive genes produced by the epithelium mediates development of other tissues. Sonic hedgehog (sHH), a known TH direct-response gene in Xenopus, is produced by the intestinal epithelium during metamorphosis. To determine the influence of sHH signaling on metamorphic intestinal remodeling, pre-metamorphic tadpoles were raised in the presence of a powerful pharmacological inhibitor of the sHH signaling pathway (cyclopamine, 20 uM). Tadpoles were then induced to metamorphose by adding TH (triiodothyronine, 5 nM) to the rearing water for 4 days. Compared with untreated controls, intestines of tadpoles induced to metamorphose with TH had constricted diameters, thickened mesenchyme, and folded epithelial layers. However, intestines of tadpoles treated with both cyclopamine and TH had larger diameters, thinner mesenchyme, and absence of epithelial folding. These findings are reminiscent of the aforementioned phenotypes produced when the intestinal epithelium is specifically prevented from responding to TH. These findings suggest that epithelial sHH signaling in response to TH plays a critical role as a mediator of metamorphic intestinal remodeling.

P1.138 NAVARRO, D*; GEORGE, EM; ROSVALL, KA; Washington State University, Pullman, Indiana University, Bloomington; *david.navarro@wsu.edu*

Does short-term HPG axis activation have long-term effects in tree swallows?

Testosterone (T) mediates many life history and behavioral trade-offs in vertebrates. Biologists interested in these effects often use implants to experimentally elevate T for prolonged periods of time. Alternatively, GnRH challenges, or injections with gonadotropin-releasing hormone, can be used to induce a transient rise in T and correlate this short-term T elevation to other aspects of an individual's phenotype. To date, GnRH challenges have not been widely used to experimentally manipulate T-mediated traits. To begin to address the possibility that GnRH challenges induce changes beyond their short-term effects on T levels, we injected free-living male tree swallows (*Tachycineta bicolor*) with either GnRH (n=17) or saline (n=9) and measured plasma T levels 30 min later. Each male had a nest with chicks, and we also quantified the rate of nestling growth over the 24h post-injection, as a proxy for male provisioning effort. Based on prior studies that suggest T decreases paternal care in many songbirds, we predicted that chicks of GnRH-males would gain less mass than those of saline-injected males. Surprisingly, we found that offspring of GnRH-males gained more mass than those of controls, despite the fact that GnRH elevated male T levels. Even within GnRH-males, the amount of T elevation was positively correlated with chick mass growth. We hypothesize that these findings stem from (a) females over-compensating for diminished provisioning by GnRH-males, (b) negative feedback clearing T from the bloodstream, or (c) other GnRH-responsive hormones enhancing paternal care. Further research is needed to tease apart these alternatives, but this study nonetheless opens the door to the use of GnRH challenges as an experimental treatment.

127.4 NAVIS, CJ*; CORNELIUS, JM; BEDNEKOFF, PA; Eastern Michigan University, Ypsilanti; *cnavis@emich.edu*

Winter corticosterone responses in American Goldfinches (Spinus tristis) in urban and rural environments

While many common songbird species use human-modified environments, the potential implications for many of these species are not well understood. Urban stressors such as reduced habitat area; high levels of light and noise; introduced competitors and predators; and limited natural food resources can result in heightened stress responses over time. While corticosterone (CORT) plays an important role in normal metabolic functions and in allowing an organism to respond to immediate threats, sustained elevated CORT levels can negatively impact an individual's health and fitness. We selected a common songbird, the American Goldfinch (*Spinus tristis*) as a model organism, and collected blood samples from individuals in urban and rural settings during winter and early spring 2016. CORT levels were analyzed from samples taken immediately and 30 minutes after capture, to assess both baseline and induced CORT responses. Initial analyses revealed no difference in baseline CORT levels between individuals using urban and rural environments, though rural birds displayed a somewhat stronger induced CORT response than did their urban counterparts. These results suggest that for *S. tristis*, the stressors of urban development are negligible, or trade off with benefits of cities such as predictable food supplementation.

P3.202 NAVON, D*; OLEARCZYK, N; ALBERTSON, RC; Univ. Massachusetts Amherst, Univ. Massachusetts Amherst; *dina.navon.3@gmail.com*

Evaluating changes in zebrafish bone deposition rates across benthic and pelagic diets

Plasticity, or the ability of a single genotype to produce multiple phenotypes under different environmental conditions, allows species to respond rapidly to changes in their environment. This response may even guide future evolution (i.e. via the flexible stem model). While it's thought that plasticity itself can evolve, little is known about its genetic underpinnings. Many teleost lineages, including African cichlids, have diverged along a benthopelagic axis encompassing coordinated shifts among behavior, morphology, and ecological niche. Importantly, some species also exhibit significant plasticity along this axis; that is, fish presented with a primarily benthic diet will look significantly different from siblings presented with a primarily pelagic diet. Previous work in our lab utilizing a cross between species that differ in their ability to mount a plastic response has identified several candidate genes that underlie this phenomenon. Importantly, many of these genes may be manipulated in the zebrafish model system. In this study, we aim to first evaluate differences in bone deposition rates across wildtype zebrafish presented with alternate biting versus suction-feeding diet treatments. Using calcium-binding fluorochromes, we labelled bone at three time-points: four weeks before treatments began, at the beginning of diet treatments, and after four weeks of treatment. We compared rates of bone deposition both before and after treatments as well as across treatments in several ecologically relevant bones. Alternate modes of feeding resulted in marked changes in craniofacial geometry, as well as in rates of bone deposition. These results set an important foundation for future work wherein the experiments are repeated in genetically manipulated animals.

67.6 NAYLOR, MF*; GRINDSTAFF, JL; Oklahoma State University; *madeleine.naylor@okstate.edu*

Males on Birth Control: Effects of 17α -Ethinylestradiol on Parental Care and Nesting Success in Zebra Finches

17α -Ethinylestradiol (EE2), found in oral contraceptives, is considered an endocrine disrupter and is often detected in sewage effluent. Both aquatic and terrestrial animals can be exposed to EE2 in the environment with potential effects on behavior and reproductive success. We tested the effects of EE2 on nest success by recording paternal care of zebra finches (*Taeniopygia guttata*) and offspring growth and survival after male exposure to EE2. We used three levels of EE2 exposure, 0 ng (control); 4 ng, which is a level found in streams near wastewater effluent sites; and 100 ng, which serves as a higher level not recorded in nature. Males were dosed orally for three weeks before males and females were introduced and treatment continued until nestlings hatched. We recorded courtship behaviors to determine if EE2 affected pair bond formation and parental care behaviors during incubation to observe if EE2 affected paternal investment. We also measured nest success via egg production, hatching success and fledging success. Males treated with EE2 have altered behavior during courtship and egg incubation, specifically time spent in the nest box, time spent maintaining the nest box and pair bond maintenance behaviors via allopreening. Preliminary data suggest that paternal EE2 treatment does not influence hatching and fledging success but may influence nestling growth as demonstrated by effects on weight gain, wing growth and tarsus growth. Collectively these data suggest that environmentally relevant levels of EE2 do affect male behavior and may affect aspects of offspring growth, therefore, making EE2 an environmental concern.

84.3 NAYLOR, E/R*; HIGHAM, T/E; University of California, Riverside; *emily.naylor@email.ucr.edu*

Navigating rough terrain: Impacts of a substrate transition on locomotion in the Namib Day Gecko

Animals must frequently negotiate variable landscapes while searching for food, pursuing mates, and evading predators. Though a multitude of studies have tested how various aspects of substrate, such as incline, compliance, and rugosity, impact locomotion, fewer have examined how animals respond to changes or transitions in substrate during a single locomotor event. Substrate perturbations represent a pertinent challenge to performance, particularly for animals moving at high speeds. Field observations of escapes between flat rock and loose dune sand led us to test the effect of a substrate transition on posture, speed, and stability in the Namib Day Gecko (*Rhoptropus afer*), a diurnal, cursorial, rock-dwelling gecko. Ten individuals were captured and recorded from a lateral position at 500 fps while running down a trackway approximately 2 meters in length. Two conditions were examined: a sandpaper control and a treatment with approximately 10 centimeters of level dune sand at its center. We measured stride variables and used body markers to measure velocity, acceleration, and body pitch over the course of an entire trial and for each stride within a trial. Duty factor increased with reduced swing time in sand strides, regardless of speed. Interestingly, average stride velocity increased in sand strides relative to pre-sand strides in approximately half of the trials, suggesting that approach speed may dictate subsequent performance. Furthermore, peak stride acceleration was typically highest in strides following the sand transition, as was body pitch, reflecting a potential loss of stability as the lizards encountered a more compliant substrate. Successful negotiation of perturbations likely depends on the right combination of these properties.

132.3 NEAL, AE*; MOORE, PA; Bowling Green State University; *nealale@bgsu.edu*

Altering duration of exposure to atrazine impacts aggressive behavior in crayfish

Anthropogenic chemicals have been shown to negatively impact freshwater organisms at sublethal concentrations. The effects of those chemicals is dependent upon several factors, including the duration of exposure. Longer exposure periods have the potential to cause both different and more harmful impacts to organisms than that of shorter exposure events. Most pollutants move through the environment in a pulsatile fashion so the concept of duration of exposure is complex and dynamic. Additionally, the toxicokinetics of some pollutants may not cause impairment following a brief exposure. To begin to understand how duration and the pulsatile nature of exposure interact to produce harmful effects in organisms, female *Orconectes virilis* crayfish were exposed to a solution containing sublethal concentrations of atrazine, an herbicide commonly used in agriculture. Crayfish were exposed for 1, 2, or 3 day periods within flow-through experimental streams. Immediately after the exposure period, crayfish fought an unexposed opponent in a 15 minute fight assay. These fight trials were recorded and later analyzed using an ethogram from Bergman and Moore (2003). Results indicate that exposure to atrazine significantly affects crayfish aggressive behavior. Results also indicate differences in aggressive behavior among the three duration treatment types.

58.6 NEDVED, BT*; FRECKELTON, M; HADFIELD, MG; University of Hawaii at Manoa; *nedved@hawaii.edu*

Bacterial Genomes and Larval Settlement: Are Predictions Possible?

Larvae of the serpulid polychaete *Hydroides elegans*, are induced to metamorphose by bacterially-produced biomolecules. Extensive work demonstrated that phage-tail bacteriocins produced by *Pseudoalteromonas luteoviolacea* (strain HI1) serve as a metamorphic cue for *H. elegans* and are composed of multiple proteins. However, little is known how widely these bacteriocins are expressed by other bacteria. We aligned and compared the genomes of fourteen strains of *P. luteoviolacea* and found homologs of six genes that are required to induce metamorphosis of H. elegans in all of the strains. Further, these genes (*macS*, *macT1*, *macT2*, *macB*, ORF2, and ORF3) are present in genomes of six additional *Pseudoalteromonas* species. However, not all inductive bacterial species have bacteriocins in their genomes, nor do all strains that have bacteriocin genes induce larvae of *H. elegans* to metamorphose. These data suggest that the bacterial intractions that cause larvae of *H. elegans* to settle and metamorphose are not the same across species in the same bacterial genus, nor across strains within the same bacterial species. Additionally, these data support other experimental data from our research that strongly implicate products other than MACs in very divergent bacterial groups where neither the MAC-producing genes nor structures resembling MACs are found.

80.3 NEEDHAM, KB*; GREIVES, TJ; North Dakota State Univ.; *katie.needham@ndsu.edu*

A Pre-Breeding Energetic Immune Challenge Delays Timing of Reproduction in Female Songbirds

In virtually all species, reproduction must be precisely timed to coordinate breeding and rearing of offspring with favorable conditions. In many bird species, early breeders often have greater reproductive success. Specifically, egg lay date in many species is an important predictor of annual reproductive output. An individual's finite energy budget must be partitioned to various bodily functions when and where it is most needed. For female birds, preparation for breeding, including recrudescence of the ovary, follicular development, yolk deposition and egg laying are energetically demanding processes that require energy allocation be directed towards these processes necessary for reproduction. Mounting an antibody response has been shown to increase metabolic rate in other vertebrates. Thus, females at this critical period may suppress immune activation in response to a pathogen and continue with reproductive preparation and risk death or mount an antibody response, which could negatively impact reproductive timing and success. Keyhole limpet hemocyanin (KLH) is a novel non-pathogenic antigen that generates a robust humoral (antibody) immune response, but does not induce an acute phase response and sickness behavior. Roughly two weeks prior to onset of egg laying wild female dark-eyed juncos (*Junco hyemalis*) were challenged with an intramuscular injection of KLH (treatment) or received physiological saline (control). Treatment was selected at random. On average KLH-treated females laid their first egg of the season 8 days later than saline-treated females. These data strongly suggest that free-living female birds forced to mount an energetically demanding antibody response delayed egg lay date, indicating a trade-off between investment in immunocompetence and reproduction under natural conditions.

113.7 NEEL, LK*; MCBRAYER, LD; Georgia Southern University, Statesboro ; *lauren_k_neel@georgiasouthern.edu*

Thermal dependence of sprint performance and critical thermal limits in ecologically distinct populations of a small ectotherm

Ectotherms are thought to be particularly vulnerable to the effects of anthropogenic climate change as they perform many fitness related behaviors within a narrow, preferred range of temperatures. The Florida scrub lizard (*Sceloporus woodi*) is a ground-dwelling lizard that occupies longleaf pine and sand pine scrub habitats in the Ocala National Forest. These habitat types differ in their dominant vegetation, canopy cover, and availability of vertical perches and thus are ecologically different. Thermal opportunity is used to describe the availability of preferred temperatures within specific habitats so as to understand the thermal constraints that may influence available activity times as well as the energy and resources spent on thermoregulation in a given environment. We used biophysical models to measure the available environmental temperatures in longleaf pine and sand pine scrub populations. The variation in thermal environments was examined in the context of the thermal sensitivity of locomotor performance. Higher operative temperatures in sand pine scrub habitats were correlated with higher critical thermal limits and thermal optima in these populations. Despite the range of preferred temperatures being the same, the data suggest that the thermal physiology of this species is evolutionarily labile. Thus variation in thermal opportunity between longleaf pine and sand pine scrub stands is likely driving the observed divergence in thermal physiology among these populations.

42.4 NELSON, D.*; STIEGLITZ, J.; HOENIG, R.; MAGER, E.; BENETTI, D.; GROSELL, M.; CROSSLEY II, D.; University of North Texas, University of Miami Rosenstiel School of Marine and Atmospheric Science; *dereknelson@my.unt.edu*

Cardiovascular Function of Sub-Adult Cobia (Rachycentron canadum) During Exercise Following Crude Oil Exposure

Exposure to polycyclic aromatic hydrocarbons (PAHs), a component of crude oil, can have detrimental effects on animal biology and can lead to physiological disruptions. Previous studies have shown that crude oil exposure decreases aerobic scope and reduces swimming performance of pelagic marine fishes. This general deleterious effect of crude oil exposure has been suggested to be based in an overall reduction in cardiovascular function however this speculation remains unverified. In this study, the impact of crude oil exposure on cardiovascular function was quantified in cobia (Rachycentron *canadum*), a marine pelagic species, with combined metabolic and swimming assessments. Our findings indicate crude oil exposure reduces stroke volume and swimming performance without affecting heart rate or aerobic scope. Overall the data suggest reduction in swim performance can be partially attributed to cardiac output limitations based on a reduction in stroke volume in the cobia.

40.7 NELSON, JA*; RIEGER, KJ; NELSON, jay; Towson Univ.; *jnelson@towson.edu*

Urban Fish: can their physiology tell us about the future of fishes faced with climate change?

Urbanization has altered the biotic integrity of urban streams. Impervious surface cover in cities decreases the fraction of precipitation that enters groundwater. Thus surface run-off is much greater following precipitation and urban stream flows and temperatures can change rapidly. This loss of groundwater can also produce lower flows in urban streams between precipitation events which alters natural thermal regimes. Urban fishes have been increasingly exposed to these changes of flow and temperature over the past 200 years. Interestingly, these changes to the hydrologic regime wrought by urbanization are identical to the changes expected from climate disruption in many regions. The blacknose dace (*Rhinichthys atratulus*) is an urban-tolerant species that exists in some of the most degraded streams around Baltimore, often to the point of being the only fish species left in a stream, yet this fish is also abundant in nearby, rural stream communities with diverse fish faunas. This gradient of urbanized streams at similar latitude, altitude and stream order, sets up an intraspecific comparative experiment from which one can test hypotheses concerning how urbanization has changed this species. Swimming performance of blacknose dace is highly predicated by the stream baseflow from where they are captured, but dace from urban streams are better sprinters and have greater endurance performance than predicted; training and de-training studies implicate phenotypic plasticity for these results. Thermal tolerance in dace is strongly determined by acclimation temperature and experiments are so far suggestive of urban fish having more plastic thermal tolerance and having their swimming performance less affected by pulses of temperature.

P3.143 NEPSHINSKY, MM*; LIECHTY, JS; MINOR, AK; TAYLOR, SS; PIERCE, AR; Nicholls State University, Louisiana State University, Baton Rouge; *mnepshinsky@gmail.com*

Determining Sex of Two Monomorphic Seabirds at the Isles Dernieres Barrier Island Refuge in Louisiana

Most seabirds are sexually monomorphic and do not display conspicuous differences in plumage or size. Two sexually monomorphic seabird species, Royal Tern (*Thalasseus maximus*) and Sandwich Tern (*Thalasseus sandvicensis*), have been intensely studied on the Isles Dernieres Barrier Island Refuge (IDBIR) in Louisiana. However, sex-bias of parameters, such as natal recruits, survivorship, foraging movements, parental care, and site fidelity, have not been addressed due to the difficulty of sexing individuals. The goal of this study was to determine if morphometric measurements are a reliable method of sex determination for Royal and Sandwich Terns. During the 2014 and 2015 breeding seasons, we captured adult Royal and Sandwich Terns, measured morphometric attributes (mass, wing chord, bill length, head+bill length, and tarsus) and collected blood samples to determine sex using molecular techniques. Analysis of blood samples identified the sex of 82 Royal Terns (57 males and 25 females) and 84 Sandwich Terns (40 males and 44 females). Discriminant function analysis (DFA) was used to determine if morphometric measurements were effective in determining sex of each species. DFA resulted in a correct classification rate of 75.6% for Royal Terns based on wing chord and head+bill length and 79.8% for Sandwich Tern based on mass and head+bill length. The ability to determine sex of monomorphic seabirds using morphometric measurements will allow for rapid sexing and enhance ecological investigation of these species.

P3.152 NEUROHR, JM*; KOOPMAN, HN; RUFFIN, TC; CALIRI, AW; KINSEY, ST; Univ. of North Carolina Wilmington; *jmn6284@uncw.edu*

Standard Metabolic Rate is Positively Correlated with Membrane Lipid Content in a Variety of Marine Invertebrates

Minimizing maintenance costs is a strategy employed by many organisms to conserve energy and thus allocate it towards survival, reproduction, and growth. It has been demonstrated that skeletal muscle fibers grow to the verge of oxygen diffusion limitation to minimize costs of maintaining sarcolemmal membrane potential in many organisms. However, the sarcolemmal/plasma membrane in cells is but one of many membrane bound compartments across which gradients must be maintained. Some of the variation in metabolic rate therefore may be explained by the costs associated with maintaining gradients across these cellular and intracellular compartments. This research tested the hypothesis that the density of membrane associated lipids was positively related to mass specific standard metabolic rate in a range of marine invertebrate species. Standard metabolic rate was assessed by measuring the oxygen consumption rate. The lipid content of each whole individual was determined using thin-layer chromatography. Non-membrane associated lipids including sterol esters, triacylglycerols, and fatty acids as well as membrane associated lipids including phospholipids and cholesterol were identified. Overall, oxygen consumption rate was significantly elevated in small individuals compared to large individuals. Membrane associated lipids were positively correlated with standard metabolic rate, while non-membrane associated lipids were not, as expected. These results indicate that the extent of metabolic compartmentalization may contribute to the variation in standard metabolic rates of marine invertebrates.

81.4 NEVELN, ID*; MURRAY, N; SPONBERG, S; Georgia Institute of Technology; *ineveln2@gmail.com*

Changes in Centralization of Control of Movement as Speed Varies

Legged locomotion requires control of numerous complex coupled systems, yet strategies employed by animals such as cockroaches allow for robust navigation through varied environments. As animals move faster, one might expect that the need for coordination becomes more important but that centralizing control is made more difficult due to limiting bandwidth. Here we expand on previous work on using mutual information (MI) as a metric for centralization to test the hypothesis that faster locomotion leads to a more centralized control architecture. In the cockroach *Blaberus discoidalis*, we estimate the MI between leg control signals and two kinematic state variables: a local measure of leg extension and a global measure of the overall limb kinematics. MI informs how much the control signal reduces the possible variability in the output variable and vice versa without assumptions of a particular model. We section a large data set of cockroaches running on flat terrain by stride frequency. The degree of centralization, as quantified by the amount of global MI minus the local MI, peaks at an intermediate stride frequency that corresponds to the previously published preferred running speed. Therefore, while centralization may have increasing benefits with speed, there is evidence that coordinating control becomes less attainable due to bandwidth constraints.

7.4 NEWHOUSE, DJ*; HOFMEISTER, EK; BALAKRISHNAN, CN; East Carolina University, USGS National Wildlife Health Center; *newhoused12@students.ecu.edu*

Transcriptional Response to West Nile Virus Infection in Zebra Finches

West Nile virus (WNV) is one of the most widespread arboviruses and a main cause of human viral encephalitis worldwide. WNV exists in a bird-mosquito transmission cycle where mammals act as dead-end hosts and passerine birds act as the primary reservoir host. The mammalian immune response to WNV has received considerable attention. However, little is known about the avian immune response to WNV. Avian taxa show variable susceptibility to WNV but what drives this variation is unknown. Thus, to study the immune response to WNV in birds, we infected captive zebra finches (*Taeniopygia guttata*). Zebra finches provide a useful model, as they are moderately susceptible to WNV, provide sufficient viremia to infect mosquitoes, and have a high-quality reference genome. We inoculated individuals with 10^4 plaque-forming units of the 1999 American Crow (*Corvus brachyrhynchos*) WNV isolate and sampled individuals (n=3 each) prior to infection and on Days 2 and 4 post-inoculation, corresponding to peak viremia. We performed Illumina RNAseq on spleens to provide an overview of their transcriptional response and performed differential gene expression analyses. In pairwise comparisons between Control, Day 2 and Day 4, we found a diverse repertoire of immune genes differentially expressed, including components of both the innate and adaptive immune response. Overall, we find broad parallels between the avian and the mammalian immune response to WNV, including the differential expression of five genes in the RIG-I pathway. We also uncover a number of immune genes not previously reported in the host response to WNV. Together with complementary immunological assays, we set the stage for future studies assessing variable immune responses to WNV among populations and taxa.

81.6 NEWMAN, SJ*; JAYNE, BC; University of Cincinnati, OH; *newmansv@mail.uc.edu*

Muscular Mechanisms and Kinematics of Rectilinear Locomotion in Boa Constrictors

Snakes use several locomotor behaviors as their speed and the terrain vary, and all but one of the major modes of terrestrial snake locomotion have known patterns of axial muscle activity that bend the body to generate propulsive forces. By contrast, as Lissmann described more than six decades ago, snakes can perform rectilinear locomotion with a straight body, and yet the underlying patterns of muscle activity have remained unknown. Hence, we obtained synchronized electromyograms and kinematics to test how the costocutaneous superior (CCS) and inferior (CCI) muscles and an intrinsic cutaneous muscle in between adjacent ventral scales (IV) of boa constrictors were used during this least understood mode of snake locomotion. The CCI muscles were active mainly during the propulsive phase when the ventral skin was maximally shortened and had static contact with the ground. Hence, CCI activity pulled the axial skeleton forward relative to both the ventral skin and the ground. The CCS activity during the recovery phase pulled the skin forward both relative to the axial skeleton and relative to the ground. The activity of the IV muscles began during the later stages of sliding contact with the ground and as the ventral skin shortened, and activity continued for almost the entire duration of static contact with the ground while the ventral skin remained maximally shortened. The snakes increased speed by increasing both the frequency and amplitude of movements as well as decreasing the portion of a locomotor cycle with static contact with the ground. With the exception of the activity of the IV during static contact with the ground when no shortening of the ventral skin occurred, our findings supported the long-standing and insightful hypotheses of Lissmann.

115.3 NEWMAN, AEM; University of Guelph; *newman01@uoguelph.ca*

The Influence of the Early-life Environment on Stress Physiology and Fitness in the Wild

Early-life conditions can have profound and lasting effects on physiology and behaviour throughout an individual's lifetime. For example, in captive songbirds, nutritional restriction or corticosterone treatment during early-life has been related to changes in hypothalamic-pituitary-adrenal (HPA) axis function, brain development and behavior during adulthood. While exposure to pre- or post-natal stress often carries negative connotations, eco-physiologists are making progress towards understanding how the early-life environment programs offspring physiology and behaviour to match the anticipated environment and how this phenotypic plasticity enables individuals to track fitness optima. However, how the effects of the early-life environment, specifically stress exposure, are manifested in the wild is not well understood. Using long-term marked wild populations of birds and mammals with relatively high natal philopatry, I examine the ecological and physiological outcomes associated with the early-life environment. Conducting large-scale field experiments, I describe the relationship between early-life conditions, stress physiology, survival and annual reproductive success.

S10.1 NEWMAN, SA*; STEWART, TA; WAGNER, GP; New York Medical College, Yale University; *tom.stewart@yale.edu*

Introduction to the symposium Physical and Genetic Mechanisms for Evolutionary Novelty

For the past century, genetic approaches have dominated explanatory frameworks for biological development. There has also been a parallel tradition, beginning even earlier, that has employed physical concepts to understand tissue morphogenesis, developmental pattern formation, and morphological variation. In recent years these two streams have begun to merge within the discipline of evolutionary developmental biology. This integration has been fostered by newer knowledge of deep conservation of molecular pathways in both animals and plants and their capacity to mobilize the often exotic physics of chemically and mechanically excitable condensed materials, as well as advances in mathematical and computational modeling of complex systems. Physical principles and processes (e.g., Turing instabilities and oscillator dynamics, viscoelasticity, fractal geometry) are being applied to developmental systems with implication for a variety of problems, notably the generation of novel characters. Despite recent efforts along these lines, the challenge remains of finding common themes among these "physico-genetic" approaches that would permit their integration into the mainstream of biological science. This symposia, entitled ‘Physical and Genetic Mechanisms for Evolutionary Novelty', aims to promote such an integration by highlighting researchers who working at the interface of these fields with the shared goal of explaining evolutionary novelty.

125.7 NGUYEN, AD*; BROWN, M; ZHITNAY, J; HELMS CAHAN, S; GOTELLI, NJ; ARNETT, A; ELLISON, AM; NGUYEN, Andrew; University of Vermont, Unity College, Harvard Forest; *anbe642@gmail.com*

Constraints on cold tolerance and hardening ability limit the distribution of forest ants at its northern range boundary.

Population range edges may result from trade-offs that limit adaptation to extreme environments. We assessed whether the northern boundary of the ant Aphaenogaster picea reflects a trade-off between intrinsic and plastic responses to low temperature. We measured occupancy with field surveys of A. picea across its northern range limit in Maine and used decision-tree models to predict occupancy from climatic variables. To evaluate cold tolerance, we lab-acclimated colonies and measured recovery time from cold shock with and without pre-exposure to a cold-hardening treatment, and estimated broad-sense genetic correlations between basal tolerance and hardening. High summer temperatures (Tmax > 24 °C) and low seasonality (SD < 101) predicted occupancy with 86% accuracy. The first eigenvector of the G-matrix revealed a trade-off between cold tolerance and hardening ability; colonies from cooler sites had higher basal tolerance but lower hardening ability than colonies from warmer sites. This suggests that populations adapt to colder temperatures by shifting from plastic to constitutive mechanisms, at the expense of coping with extreme events. Constraints imposed by physiological trade-offs may be an important determinant of poleward range limits in A. picea.

P3.92 NGUYEN, K*; STAHLSCHMIDT, ZR; Univ. of the Pacific; *zstahlschmidt@pacific.edu*

Fighting in the heat: Effects of temperature on aggression and agonistic outcomes

Agonistic behavior (i.e., fighting) is an important component of intraspecific competition for many animals. Often, outcomes of agonistic contests serve as an indicators of individual fitness, helping the victors secure critical resources (e.g., territory, food, and/or mating rights). Though several factors affecting aggression have been well-−documented across taxa (e.g., variation in age or body size), there have been few studies examining the effects of abiotic factors on aggression and outcomes of agonistic contests. Field crickets have been an ideal model for examining aggression in past studies. Thus, to examine the role of temperature on agonistic behavior, male sand field crickets (*Gryllus firmus*) were maintained throughout adulthood in a diel temperature cycle mimicking thermal conditions in their native range during the active season (20.5°C - 32°C). A 2 x 2 factorial design of agonistic contests was implemented where agonistic contests were staged between size-−matched and size−mismatched pairs of males, and at cool (22°C) and warm (32°C) periods in the diel temperature cycle. Age, wing morphology, and reproductive status were controlled—all males were short-winged, 7-8 day old adults, and virgin. Agonistic encounters were video−-recorded and analyzed to determine each individual's level of aggression (scored using well-established ethograms for *Gryllus* crickets) and ultimate outcomes (i.e., who won and lost). Our results will elucidate the role of a prominent abiotic factor (temperature) in the modulation of aggression and agonistic outcomes, and future studies will disentangle the effects of photoperiod and temperature.

26.4 NGUYEN, KD*; YU, N; BANDI, MM; VENKADESAN, M; MANDRE, S; Yale University, Tsinghua University, Okinawa Institute of Science and Technology, Brown University; *khoi.nguyen@yale.edu*

Curvature-induced stiffening of rayed fins

Fishes switch between locomotive modes as ecological needs vary, and this requires rapid and substantial modulation of fin stiffness. Motivated by the commonplace observation that a thin sheet of paper stiffens upon slightly curling it, we analyze the mechanics underlying the stiffness of thin structures like fins. For a thin sheet of paper, transverse curvature couples out-of-plane bending with in-plane stretching, and thereby stiffens it. Although rayed fins are a composite of rays and membranes and not homogeneous like a sheet of paper, we show that a similar mechanical principle carries over, with variation of the intrinsic ray geometry between adjacent rays playing the role of transverse curvature. The ray has a preferred bending direction if the two principal area moments of the ray's cross section are dissimilar, such as for a non-circular cross-section. Now, a systematic variation in the principal bending axes between adjacent rays will couple ray bending with membrane stretching, the same principle as a curled sheet. Using µCT imaging, we find that the rays in the mackerel's pectoral fin have a non-circular cross-section, and the preferred bending axis varies systematically across adjacent rays. Our mathematical analyses identify key material and morphological parameters that affect the fin's stiffness, and its maximal range of variation. As a result of its morphology, we predict that the mackerel's pectoral fin can vary its stiffness over 5-fold by controlling the transverse curvature. We also show that even when the fin appears flat, the ray geometry leads to a "functional curvature", i.e. morphological elements that couple ray bending and membrane stretching.

P3.78 NICHOLS, J*; SMITH, J; JACK, A; SKOPEC, MM; Weber State University; *jennifernichols@mail.weber.edu*

Caching and Activity Levels in Woodrats

Woodrats (genus *Neotoma*), also commonly known as packrats, exhibit prolific caching behaviors. Items collected by woodrats include food and items for nest building, as well as things that seem to serve no function, such as shiny objects. Woodrats' interest in non-useful objects may be a spill-over behavior from food caching and/or high activity levels. While activity, food and object caching have been tested independently in woodrats, all three have not been measured in the same experiment. We therefore investigated activity, food and object caching in a laboratory setting in three different woodrat populations, *N. albigula,* and two populations of *N. lepida* from the Mojave and Great Basin Deserts. To test for differences in caching behavior in relation to activity, woodrats were placed in nesting cages that connected to a secondary area where they had access to a running wheel, rabbit chow (food), and jingle bells (object). It was found that both populations of *N. lepida* handled more jingle bells than *N. albigula*, indicative of a greater drive to cache non-essential items. Conversely, *N. albigula* showed a greater drive to cache an essential item, food, and cached more food than both populations of *N. lepida*. Both *N. lepida* populations had higher activity levels than *N. albigula*, as measured by the distance run on the wheels. Based on *N. lepida's* higher activity levels and interest in jingle bells we propose that interest in non-useful objects may be a spill-over behavior from high activity levels. *N. lepida's* high activity levels and interest in novel items may have allowed them to colonize a greater diversity of habitats than *N. albigula*.

87.7 NIEDOJADLO, J*; BURY, A; CICHON, M; SADOWSKA, ET; BAUCHINGER, U; Jagiellonian University; *jowita.niedojadlo@doctoral.uj.edu.pl*

Daily Energy Expenditure, but Not Self-Maintenance Costs, Are Related to Hematological Variables in Response to Temperature Acclimation

Thermoregulation accounts for a substantial part of an endothermic animal's energy budget. Higher metabolic requirements due to thermoregulation are typically met by aerobic metabolism, thus temperature acclimation may also affect oxygen supply via the blood. We investigated the relationship between metabolic rates (MRs) and hematological variables (HVs), specifically hemoglobin concentration (Hb); hematocrit (Hct); red blood cell count (RBC_c) and red blood cell area (RBC_{area}) in birds acclimated to different temperatures. Female zebra finches (*Taeniopygia guttata*) were maintained for seven weeks either in cold T_a = 12 °C (N = 39) or thermo-neutral T_a = 32 °C conditions (N = 40). Following acclimation, we also determined mass specific food intake, basal metabolic rate during rho phase ($BMR_ρ$) and maximum metabolic rate (MMR); we drew blood samples to measure HVs. Principal component analysis (PCA) was used to reduce the number of variables and its components were used to analyze the relationship between HVs and MRs. Body mass and food intake were higher in cold- than in warm-acclimated birds, while $BMR_ρ$ and MMR were not different between the temperatures. Principal component analysis revealed that PC1 explains 63% and PC2 25% of the variations, with Hb, Hct, and RBCc grouping in PC1 with equally high, positively related Eigenvalues. Erythrocyte area (RBC_{area}) largely accounted for PC2. Both PC1 and PC2 were negatively related to food intake, but not significantly related to $BMR_ρ$ and MMR. Lower values for Hb, Hct and RBC_c in concert (PC1) and smaller red blood cells (PC2) relate to higher food intake. The HVs appear to be negatively related to daily energy use, but not related to energy costs of self-maintenance.

P3.105 NIEDZIALEK, O*; GIANNONI-GUZMAN, M; GIRAY, T; OSKAY, D; AGOSTO-RIVERA, J. L.; Bard College, Univ. of Puerto Rico, Rio Piedras, Namik Kemal Universitesi; *on2032@bard.edu*

Development of a Method for Large Scale Tracking and Analysis of Honeybee Behavior

Honeybees are well known for the highly complex and organized roles they play in colonies of thousands of individuals, yet they have not yet been studied on a large scale to discover the effects of the division of labor on the hive as a whole. We recently selected a colony of *A. mellifera carnica* at Namik Kemal Üniversitesi in Degirmentalti, Turkey as our study site to investigate the automation of the analysis of multiple complex social behaviors on an individual and community scale in honeybees. This was done by creating a long-term recording network that will be able to track movements of multiple generations of bees for a year long period. Previous studies have used tagging when tracking bees, but have not been able to distinguish between fanning and pollen collecting. We highlighted these behaviors to understand how they impact the circadian rhythm of a single bee, and discover at what time of day they leave the hive to complete these actions. Current monitoring systems like RFID tracking are unsuitable because they can only track a single bee at a time, but by using a modified version of BEETag software, we will be able to track multiple generations of groups of ~500 bees for their entire lifespan. This will be completed through a camera system that will give us 24/7 video of the bees entering and leaving the hive. Current data mining algorithms are not sufficient for video analysis of this complex behavior, which is why we aim to develop a semi-supervised, learning algorithm that can quantify these usually solely manually annotated behaviors. This study design is unique for the year long recording it will facilitate, and discovering which individuals are responsible for nectar/pollen collecting and fanning all in their natural habitat.

45.5 NIELSEN, M.E.*; MAPPES, J.; University of Arizona, University of Jyväskylä; *nielsenm@email.arizona.edu*

Interactions between Color and Behavior for Aposematic and Thermoregulatory Functions in a Caterpillar

To maximize their fitness, organisms must perform many different tasks; however, the ideal phenotype for these tasks may differ, leading to functional tradeoffs. For example, an aposematic animal's color is not only important to warn predators of their distastefulness, but also affects temperature. Nevertheless, many different traits can influence a given task, and thus to fully understand how these functions are performed, we must consider multiple traits. In addition to color, behavior can also influence both exposure to predators and temperature. We studied how color pattern and behavior interactively influence both temperature and predation risk in the caterpillars of *Parasemia plantaginis* (the wood tiger moth). We measured the effects of color and position (hidden vs exposed) on the temperature of live caterpillars, and measured the temperatures at which caterpillars of different patterns adopted different positions. We then used *Parus major* (great tits) as model predators to evaluate the how color and position interacted to determine relative predation risk. Live caterpillars hid very rarely except at high temperatures, an initially puzzling behavior which is explained by the fact that not only are exposed caterpillars warmer, but also safer from predators than hidden caterpillars. In contrast, the optimal color for thermoregulation and predator-avoidance did appear to differ, but their effect was much smaller than the effect of position. Ultimately we've shown that although functional tradeoffs do exist for some traits, for other traits the same phenotypic values may often be optimal for multiple functions. Both of these cases can occur in the same organism, and thus to fully understand how an organism meets an environmental challenge we should consider multiple traits and the other functions those traits may contribute to.

S10.12 NIJHOUT, H.F.*; MCKENNA, K.Z.; REED, M.C.; Duke University; *hfn@duke.edu*

The origin of novelty through the evolution of scaling relationships

Morphological novelty is often thought of as the evolution of an entirely new body plan or the addition of new structures to existing body plans. However, novel morphologies may also arise through modification of organ systems within an existing body plan. The evolution of novel scaling relationships between body size and organ size constitutes such a novel morphological feature, and morphological novelty can arise through evolutionary changes in the relative growth of body parts. Insects provide excellent examples of evolutionary novel allometries, displaying some of the most exaggerated traits in the animal world, e.g. eyes on the ends of long stalks, forelegs longer than twice the body length, and horns that emerge from the head and thorax. Experimental studies have demonstrated that there is genetic variation for allometries and that scaling relationships can evolve under artificial selection. A natural question that arises is: what kinds of changes in the underlying developmental processes can yield shifts in scaling relationships? We will discuss how changes in nonlinear growth kinetics can give rise to novel allometric relationships. Using wing-body scaling in Manduca sexta, we show that the size attained by wings depends on parameters that influence both body growth and wing growth. Several different combinations of parameters can yield similar scaling relationships. We describe how parameters change under directional and stabilizing selection on body size, wing size and relative wing size. Finally, we demonstrate how novel morphologies can arise by evolutionary change in growth kinetics.

S11.1 NILSSON, Dan-E.; Lund University, Lund, Sweden; *dan-e.nilsson@biol.lu.se*

Behavioural drive and performance continuity: the why and how in eye evolution

Simple roles for photoreception are likely to have preceded more demanding ones such as vision. The driving force behind this evolution is the improvement and elaboration of animal behaviours using photoreceptor input. Because the basic role for all senses is to support behaviour, I argue here that this 'behavioural drive' is more relevant than the popular concept of "sensory drive". Photoreception serves many different types of behaviour, from simple shadow responses to visual communication. Based on minimum performance requirements for different types of tasks, photoreceptors have been argued to have evolved from non-directional receptors, via directional receptors, to low resolution vision, and finally to high resolution vision. Through this sequence, the performance requirements on the photoreceptors have gradually changed from broad to narrow angle reception and from slow to fast response. Also the requirements of high absolute sensitivity and good signal/noise ratio are likely to have increased as photoreceptors have taken on the control of ever more advanced and demanding behaviours. We can assume that the first animal behaviours required only very simple and low-performance sensory input. Selection for more efficient behaviours would drive evolution towards better sensory performance, and this in turn would allow for evolution of new and more demanding behaviours as soon as the sensory performance reaches the minimum requirements of the new behaviour. Here I use photoreception as examples to show that new behaviours would only evolve if their sensory performance requirements to some degree overlap with the corresponding requirements of already existing behaviours. I argue that this need for sensory 'performance continuity' in the behavioural drive has been one of the most important factors guiding animal evolution.

146.2 NILSSON, B*; BUCKLIN, A; JEPSEN, PM; HANSEN, BW; Roskilde University, Roskilde, Denmark, University of Connecticut, Avery Point, Connecticut; *binibe@ruc.dk*

Do copepods experience stress caused by experimental handling?

Handling of animals is conditional when performing experiments. When using stress-related gene transcription as a molecular marker in stress studies, it is important to consider handling in order to potentially contribute to optimal experimental design. *Acartia tonsa* is a well-studied calanoid copepod concerning basic physiological and ecotoxicological responses besides argued as a relevant live feed for fish larvae in the aquaculture sector. In order to create optimal experimental designs for transcriptional analysis on *A. tonsa* it is important to know the potential effect caused by handling on stress-related genes. Nauplii and adult individuals of *A. tonsa* were placed on a plankton filter up to 10 minutes to represent a typical handling situation. As a positive stress control, a salinity shock (from a regulator salinity of 35 to 5) for up to 10 minutes was used. The negative stress control consisted of non-handled individuals. The copepods were stained with neutral red in order to examine mortality caused by handling. Nauplii survival percentage was close to 100% after 10 min of handling, while the adults exhibited a survival of just 45-61% with the same treatment. Since the adults are more sensitive towards handling, we decided to focus on the adults solely in the following gene transcriptional analysis. For the transcriptome analysis (RNAseq) individuals of *A. tonsa* were grown from eggs to adults in culture flasks at optimal conditions in order to avoid any handling or stress. The aim of this study is to create awareness of the potential handling effects in studies involving transcriptional gene analysis. We want to examine the effects in the calanoid copepod, *A. tonsa*, and identify genes involved in handling stress.

P1.204 NISHIKAWA, K; TAHIR, U; RIVERA, D*; Northern Arizona University; *Djr294@nau.edu*

Modeling ex vivo muscle activation may improve force predictions in a winding filament muscle model.

Muscle models that incorporate activation, force-length, and force-velocity properties of muscle perform poorly at predicting forces in work loop experiments. One reason for this failure is that many models do not account for force enhancement with stretch or force depression with shortening. The winding filament hypothesis seeks to explain these phenomena. The hypothesis suggests that titin binds to thin filaments in muscle sarcomeres upon calcium influx, and that myosin cross-bridges wind titin onto thin filaments during force development. In the model, myosin cross-bridges are represented as a damped contractile element with a force-length relationship. Thin filaments are represented by a pulley with radius R, around which a damped titin spring is wrapped. The pulley system is in series with a tendon spring. Activation of the contractile element rotates the pulley, stretching and storing elastic energy in the titin spring. External forces applied to the muscle also extend or shorten the titin and tendon springs. The model uses first order differential equations that describe its kinematics and kinetics, but does not currently include equations to convert muscle stimulation into muscle activation. Incorporation of a stimulation-dependent activation function that approximates calcium dynamics improves the accuracy of WFH model predictions of force development, tetanus, and relaxation during isometric stimulation of mouse soleus muscles at frequencies ranging from 15hz-90hz. This method also improves force predictions of mouse soleus undergoing variable length changes under stimulation at 15hz-75hz. Converting ex vivo stimulation to changes in activation by this method may assist with the development of dynamic muscle models and allow for more accurate predictions of muscle force during work loop experiments.

P3.249 NOCHIMSON, JM*; HESLIN, ME; ROSE, CS; James Madison University; *rosecs@jmu.edu*

Testing for phylogenetic and life history effects on the shape trajectories of salamander feeding skeleton

Amphibians are unusual among vertebrates in retaining their pharyngeal arch (PA) skeleton as cartilage, developing distinct larval and adult versions of this skeleton in metamorphosing forms, and adapting the adult skeleton for different styles of prey capture. We have proposed that amphibians evolving a metamorphosis was contingent on using cartilage to make and reshape their feeding skeleton. We have also argued that the need for a fully functional feeding skeleton right after metamorphosis requires that the larval skeleton grow with little change in shape. Adult skeletal growth, however, would be expected to vary with the biomechanics of feeding, which differ significantly between tongue protruding and tongue projecting salamanders. Alternatively, if larval growth is not isometric, life history variation could affect both larval and adult skeletal shape in complex ways. This study quantifies and compares the rate of change in shape of the gape and of three PA cartilages (Meckels cartilage, ceratohyal and first ceratobranchial) during larval and/or postmetamorphic growth in eight plethodontids, three ambystomatids, and one dicamptodontid. The plethodontids include six metamorphosing and two direct developing species, and the ambystomatids include two metamorphosing and one paedomorphic species. Gape and cartilage widths and lengths are used to generate allometric equations that are tested for significant differences in the rate of shape change between different elements in the same species, between the same element in different species, and between the same element in the same species at larval and postmetamorphic stages. Species are compared to test for the effects of phylogeny and life history, and to test predictions about the role of cartilage strength and lightness in tongue projection.

100.2 NOEL, A*; MARTINEZ, A; JUNG, H; TSAI, TW; HU, DL; Georgia Institute of Technology; *alexis.noel@gatech.edu*
Cat Tongue Velcro
A cat's tongue is covered in an array of spines called papillae. These spines are thought to be used in grooming and rasping meat from bones of prey, although no mechanism has been given. We use high-speed video to film a cat removing cat food deeply wedged into a 3-D printed fur mat. We show that the spines on the tongue act as Velcro for particles. The tongue itself is highly elastic, while the spines are rigid. As the cat presses it against a substrate, the tongue flattens and the spines separate. When the tongue is removed from the substrate the spines come together, wedging particles between them. This elasticity-driven entrapment permits the surface of the tongue to act as a carrier for hard to reach particles, and to increase the efficacy of grooming and feeding.

P2.156 NOLAN, BG*; MUSCEDERE, ML; Hendrix College, Conway AR; *nolanbg@hendrix.edu*
How Do Pheidole dentata Ant Workers Compensate For Antennal Injuries When Following Pheromone Trails: Critical Periods And Odor Sampling Strategies
Pheromone trails are chemical signals used by many ant species that allow nestmates to communicate the location of important resources, making them crucial mediators of colony behavior. Workers rely on olfactory antennal sensilla to follow trails and respond to other socially relevant odors, hinting that antennal damage could severely compromise task performance and social integration. However, our previous work suggests that *P. dentata* ants have the ability to partially compensate for early-life loss of one antenna when performing important odor-mediated tasks, such as trail following, despite lacking the ability to use tropotaxis. Because young workers undergo substantial neuroanatomical and neurochemical maturation soon after enclosion, they may be well suited to recover from early injuries. This study varied the timing of antennal injuries with respect to worker eclosion and the duration of the post-injury recovery period, then tested workers at two ages (15 and 30 days) to assess trail following performance. Workers were filmed following artificial pheromone trails inside a custom 3D printed arena, then image-analysis software was used to quantify worker trajectories and antennal and body movements. Workers that received injuries earlier in life appeared to follow more accurately than same-aged individuals lesioned later. Additionally, injured ants adopted an alternative odor sampling strategy by broadly sweeping their remaining antenna in front of their path, unlike control ants that held their two antennae in a stable orientation. These results shed light on injury-related behavioral plasticity and the ability of workers to compensate for substantial sensory injuries despite their tiny nervous systems, which may enhance social resilience.

P2.123 NOLAN-TAMARIZ, MA*; IYENGAR, VK; Villanova University; *mnolanta@villanova.edu*
Forceps and Foreplay: Sexual Selection in the Maritime Earwig, Anisolabis maritima
Sexual selection can lead to dimorphic traits arising from intrasexual selection (armaments), intersexual selection (ornaments), or a combination of both. We studied the roles of body size and weaponry in the mating system of the maritime earwig *Anisolabis maritima*, an insect where males are more variable in size (and often larger) than females and possess asymmetrical, curved forceps instead of the straight ones seen in females. The fact that both males and female possess weaponry belies their aggressive nature and risks of injury when interacting with conspecifics, which may have implications on both courtship and fighting among potential partners. In this study, we videotaped randomly-selected pairs of earwigs and recorded their behaviors over 2 hours to determine the effects of size and weaponry on aggression vs. courtship interactions. We found that males, but not females, show size-based courtship, as smaller males were more likely to engage in courtship behavior. We also found that females, but not males, show size-based aggression, as females increase the frequency of strikes directed at males based on how large they are relative to the male. Furthermore, there is a positive relationship between the frequency of interactions and courtship behavior for females only, and this pattern is driven by the number of strikes that females direct at males. Taken together, our results demonstrate the females are more sexually receptive to smaller males with whom they engage in aggressive acts, which suggests that females may use aggression to assess the quality of or threat posed by those smaller potential partners.

134.5 NORIN, T*; GAMPERL, A.K.; University of Glasgow, United Kingdom, Memorial University of Newfoundland, Canada; *tommy.norin@glasgow.ac.uk*
Metabolic scaling of individuals vs. populations: experimental evidence for variation in scaling exponents at different community levels
The power scaling of metabolic rate with body mass is fundamental to animal biology, due to the profound influence that animal size has on ecology and physiology, yet the value of the scaling exponent (*b*) is highly debated. *b* has been suggested to be fixed at 0.67 or 0.75, or to vary systematically with cell size and metabolic intensity, within the boundaries of 0.67 and 1. Despite this tremendous interest in the value of scaling exponents, little is known about metabolic scaling within individual animals and how this relates to population-level scaling. We conducted a long-term study that repeatedly characterised the entire metabolic profile of 68 individual fish (cunner, *Tautogolabrus adspersus*) by measuring their standard metabolic rate (SMR), routine metabolic rate (RMR), active metabolic rate (AMR), and aerobic scope (AS) in five separate trials over 10 months (full fish mass range, 0.5-19.5 g). The mean exponents for the experimental population of fish at any single point in time (*i.e.*, within trials; b_{SMR}=0.89, b_{RMR}=0.89, b_{AMR}=0.94, b_{AS}=0.96) were higher than those characterising the population as it aged (*i.e.*, across all trials; b_{SMR}=0.82, b_{RMR}=0.84, b_{AMR}=0.90, b_{AS}=0.92), and both were higher than the mean exponents for individual fish (b_{SMR}=0.74, b_{RMR}=0.79, b_{AMR}=0.83, b_{AS}=0.85). This variation in scaling pattern, occurring across different levels of community structure, has implications for bioenergetics- and ecosystem models, and suggests that studies on population dynamics should apply metabolic scaling exponents that are significantly higher than those used in studies on individuals.

61.2 NORIN, T*; METCALFE, NB; University of Glasgow, United Kingdom; *tommy.norin@glasgow.ac.uk*
Plasticity, performance, and pace of life: individual differences in physiological and behavioural flexibility towards daily changes in temperature and oxygen availability
Individual animals differ consistently in both their physiology and behaviour. Jointly, this variation sets the ‘pace of life' of individuals under different environmental conditions. Given the increased frequency of extreme weather events already occurring as a result of climate variability, the ability to adjust (or maintain) performance when faced with rapid environmental changes is likely to affect individual fitness. Using fish as examples, we here show how individual phenotypes vary in both their metabolic and behavioural flexibility when exposed to daily changes in temperature and oxygen availability (hypoxia). We show that phenotypes with high metabolic rates and more intense behaviours are less responsive to increased temperatures but more affected by hypoxia, with the opposite being true for phenotypes with a slower pace of life. This shows that the ability of different phenotypes to respond to rapid environmental changes is not the same across environmental contexts and suggests that any selection for specific phenotypes will depend on the environmental stressor the animals are faced with.

82.4 NOTAR, JC*; GORDON, MS; Duke University, Univ. of California, Los Angeles; *julia.notar@duke.edu*
Future Directions in the Whole Body Eye of Sea Urchins: Effects of Phylogeny, Light Intensity, and Spine Density
Sea urchin behavioral reactions to light are more complex than previously thought. These animals have a diffuse photoreceptive system with at least two types of opsins expressed throughout their epidermis. Essentially, each urchin functions as a large compound eye. Their dermal light sense facilitates behavioral tasks that even include coarse spatial vision. This is novel, as diffuse dermal photoreception is generally assumed to mediate non-visual tasks. It has been suggested that urchins inhabiting rocky reefs use spatial vision to locate dark crevices to hide from diurnal predators. It is commonly thought that animals have photoreceptive and visual abilities that correlate to the complexity of their light-guided behaviors. The goal of this investigation was to determine the thresholds of urchin photoreception and spatial vision in the context of environmental relevance. Underwater irradiance was measured in the field to confirm environmentally relevant levels of light to test. Laboratory behavioral trials were conducted to establish the lower limits of intensity required for spatial tasks and image resolution of three Eastern Pacific urchin species: *Centrostephanus coronatus*, *Strongylocentrotus purpuratus*, and *S. franciscanus*. Results indicate that higher light intensities and larger targets lead to more accurate visually-guided responses from urchins of all species. In addition, each species exhibited consistent responses to targets above a certain size: *C. coronatus* > 22°, and *S. purpuratus* and *S. franciscanus* > 27°. Describing the function of the urchin as a compound eye allows us to understand how these animals perceive their environments and make choices based on visual cues.

40.3 NOURABADI, N*; NISHIGUCHI, M.K.; New Mexico State University; *nish@nmsu.edu*
Fitness consequences of pH adaptation in an experimentally evolved beneficial symbiosis
Experimental evolution has been widely used as an effective laboratory technique for examining bacterial adaptation to a variety of conditions, and whether bacteria evolve new strategies to overcome the onslaught of diverse selection pressures. Abiotic variation caused by environmental fluctuations can influence the selection of specific bacterial phenotypes, the diversity within a microbial community, and the overall fitness of strains that can accommodate abrupt changes. The symbiotic association between the bioluminescent bacterium *Vibrio fischeri* and sepiolid squids (Cephalopoda: Sepiolidae) is an excellent model system to study the evolutionary ecology between host selection and symbiont specificity using experimental evolution. Since *Vibrio* bacteria are environmentally transmitted, they are subject to a wide variety of abiotic variables prior to infecting juvenile squids and must be poised to survive in both environmental and host habitats. Therefore, to gain insight as to whether selection of specific environmental phenotypes influences the fitness of *V. fischeri*, we used an experimental evolution approach to ascertain whether strains experimentally evolved to pH stress were more efficient at colonization compared to their ancestral lineages. Results show evidence that low pH adapted symbiotic *Vibrio* strains had more efficient colonization rates than their ancestral strains. In addition, growth rates had significant differences compared to ancestral strains at pHs 6.5, 6.8, and 7.2. Bioluminescence production of evolved strains improved at low pH concentrations (6.5-7.2), and evolved strains had increased luminescence inside squid light organs. Results from this study imply that adaptation to low pH increases the overall fitness of *V. fischeri*, allowing the evolved strains to be more successful in squid-host colonization.

91.3 NOVARRO, AJ; University of Maryland, College Park; *Anovarro1@gmail.com*
Geographic patterns of thermal tolerance in a widespread lungless salamander
Thermal tolerance plays a major role in determining species distributions across space and time. By defining the range of temperatures in which a species can survive and reproduce, thermal limits constrain the location and range of suitable habitats. For ectotherms, thermal tolerance breadth increases with latitude, which is driven by a decrease in lower thermal limits at higher latitudes. Upper thermal limits are generally conserved across species, suggesting that ectotherms have a limited potential to adapt to the rapid increase in temperature predicted with anthropogenic climate change. However, populations within a species, especially widespread species, may exhibit variation in thermal limits. Such variation plays a critical role in predicting the resilience of species to climate change. Here, we measure critical thermal minimum and maximum in a lungless salamander species, *Plethodon cinereus*, from North Carolina to Maine to determine whether thermal limits and thermal tolerance breadths vary among populations in relation to environmental temperature. *Plethodon cinereus* is the most widely distributed *Plethodon* species in the eastern US, extending farther north than any other lungless salamander. Given that lungless salamanders are dispersal-limited and physiologically sensitive to temperature, we predict that thermal limits will reflect the environments in which they live. Further, we predict that *Plethodon cinereus* has been able to exploit such a large geographic range through local adaptation of thermal limits. By measuring the environmental drivers of thermal limits in a widespread species, this study will contribute to our understanding of species' distributions and potential responses to climate change.

80.7 NUNEZ, CMV*; ADELMAN, JSA; CARR, HA; KNIGHT, C; RUBENSTEIN, DI; Iowa State Unviersity, Princeton University; *nunezcmv@iastate.edu*

Prolonged Effects of Contraception Management on Feral Horse (Equus Caballus) Reproductive Physiology and Behavior

Due to the extirpation of their natural predators, feral horse populations have expanded across the United States, necessitating their management. Contraception of females (mares) with porcine zona pellucida (PZP) is a popular option; however, effects to physiology and behavior can be substantial. For example, on Shackleford Banks, North Carolina, USA, treated mares have extended ovulatory cycling into the non-breeding season, resulting in later foaling dates, and have demonstrated decreased fidelity to the band stallion, changing social groups more frequently. However, PZP's long-term effects on mare physiology and behavior remain largely unexplored. After the contraception program was largely suspended on Shackleford Banks in 2009, we examined how prior exposure to varying levels of PZP treatment impacted 1) foaling probability and foaling dates from 2009-2014 and 2) mare fidelity to the band stallion during 2013 and 2015. Mares receiving any level of prior PZP treatment were less likely to foal than were untreated mares. Additionally, previously treated mares continued to give birth later than did untreated mares. Finally, mares previously receiving 4 or more treatments continued to change groups more often than did untreated mares, while mares previously receiving 1-3 treatments did not. Our results suggest that although PZP-induced infertility and its associated behavioral effects can persist after the cessation of treatment, these effects can be ameliorated for some factors. Careful consideration to the frequency of contraceptive treatment is important to maintaining more natural physiological and behavioral functioning in wildlife populations.

37.5 O'BRIEN, DM*; BOISSEAU, R; SOMJE, U; DUELL, M; EMLEN, DJ; University of Montana , University of Florida , Arizona State University , University of Montana; *devin.m.obrien@gmail.com*

The metabolic costs of animal weapons

Sexually selected traits are the most extreme structures in the animal world. Ornaments and weapons, as vital components of reproductive success, have a long history of intense selection that has led to the bizarre forms we know today. Weapons are especially massive and, in some species, comprise over half the animal's body mass. Based on first principles, these traits look like they should be expensive. Yet, we know surprisingly little about the strain these traits place their bearers. Only a handful of studies have explicitly measured the costs associated with sexually selected traits and those studies remain inconsistent. Some weapons appear to carry high costs while others do not. Here, we work to reconcile this inconsistency by exploring one hypothesized cost to sexually selected traits - metabolic strain. Using flow through respirometry, we measure resting metabolic rate across four insect systems to better understand how this metric of cost changes with increasingly large weapon sizes both within and among species. Our results suggest that metabolic costs within weapon systems are highly variable. In fact, seemingly similar weapons show extreme differences in resting metabolic rate, and show little correlation between weapon size per se and metabolic rate. Instead, metabolic costs in these systems appear to result from the large degree of muscle mass associated with some weapons. Indeed, when the metabolic costs of these weapons systems are analyzed in the context of muscle mass, they fall onto a linear spectrum where those animals with the largest amount of muscle directly associated with their weapons bear the most extreme metabolic costs.

5.6 O'BRIEN, HD; Oklahoma State University Center for Health Sciences; *haley.obrien@okstate.edu*

Selective Brain Cooling as an Artiodactyl Key Innovation for Climate Change Survivorship

The fossil record is the most valuable source of historical data regarding organismal response to climate change. Conservation paleobiology has focused on changes in species abundance, range size shifts, & population dynamics inferences using ancient DNA. Few studies directly incorporate thermoregulatory capacity into historical models. One promising avenue to explore how changes in thermoregulatory capacity can influence climate-related survivorship is selective brain cooling (SBC) in even-toed ungulates. Artiodactyls can decouple brain from body temperature by up to 4ºC. SBC mitigates heat-stress & decreases evaporative water loss; as such it may insulate diversity as climate warms and dries. SBC is facilitated by an intracranial arterial meshwork called the carotid rete (CR), which replaces the internal carotid artery. Presence of a CR is accompanied by consistent remodeling of basicranial osteology, enabling direct tracing of enhanced artiodactyl thermoregulation in fossils. Using osteological correlates from 700 fossil specimens, SBC presence & absence was inferred for 279 extinct artiodactyl species. Of 24 extinct families, 14 lack SBC. Occurrence-based paleobiology modeling was used to calculate trait-specific Cenozoic diversification rates for artiodactyls with & without SBC. Results indicate negative speciation rates for artiodactyls without SBC during periods of aridification, ultimately resulting Miocene extinction. Contrarily, artiodactyls with SBC have increased diversification, even across environmental drying. By recent definitions, a structure is a key innovation if organisms that do not possess it are demonstrably more susceptible to extinction. SBC is a key innovation, implying that artiodactyls may be more amenable than other large mammal species to warming & drying climates.

P1.234 O'DONNELL, MK*; DEBAN, SM; University of South Florida; *mkodonnell@mail.usf.edu*

Who Needs Toe Pads? Climbing in Plethodontid Salamanders

Climbing has evolved multiple times in family Plethodontidae. In the absence of specialized toe pads or claws common to other scansorial organisms, salamanders climb on rough and smooth surfaces through either gripping via the toes, adhesion of the ventral skin surface, and in some species, by suction. Clinging and climbing performance on a smooth acrylic surface was examined in multiple climbing and non-climbing species within Plethodontidae to determine the maximum angle at which performance was maintained. Functional adhesive surface area and climbing kinematics during locomotion at various angles were quantified with an edge-illuminated acrylic sheet using frustrated total internal reflection. Significant variation in climbing ability on smooth surfaces was found among species, with the most adept climbing species performing comparably to tree frogs that possess adhesive toe pads. Variation in climbing performance could be accounted for by behavioral adaptations to enhance movement on smooth, inclined, and vertical surfaces or by species-specific attachment mechanisms, such as increased skin stickiness or suction. Maintenance of climbing performance over a wide range of body masses was observed in some scansorial species; in many non-climbing species, climbing ability was strongly limited by functional surface area in relation to body mass. Variation in the minimum relative surface area necessary to maintain attachment at high angles suggests species-specific attachment mechanisms benefit climbing species.

59.6 O'MARA, MT*; WIKELSKI, M; VOIGT, CC; TER MAAT, A; POLLOCK, HS; BURNESS, GP; DESANTIS, LM; DECHMANN, DD; Max Planck Inst. for Ornithology; Univ. Konstanz; Smithsonian Tropical Res. Inst., Max Planck Inst. for Ornithology; Univ. Konstanz, Leibniz Inst. Zoo & Wildlife Research, Max Planck Inst. for Ornithology, Univ. Illinois at Urbana-Champaign, Trent University; *tomara@orn.mpg.de*

Counter Strategies to High Metabolic Rates and Rapid Changes in Energy Expenditure in Frugivorous Bats

The maintenance of the energetic cost of life within an ecological context, though crucial, remains poorly understood for most animals. Bats are the only truly flying mammals, and execute an explosive switch from immobile states to energetically expensive flight. We took a multi-pronged approach to estimate how tent-making bats (*Uroderma bilobatum*) manage their high-energy lifestyle fueled primarily by fig juice. We measured instantaneous and total daily energetic expenditure via heart rate telemetry of free-flying bats; how quickly ingested food enters metabolism and is incorporated into fat through carbon dioxide isotopes of breath; and the potential for energy mobilization by glucocorticoids. Daily energetic expenditure of *Uroderma* is 46 kJ with a sustained metabolic scope 5.39. They maintain this through unusual cyclical depressions in resting heart rate to less than 200 bpm that save 10% of daily expenditure and counter flying heart rates of over 900 bpm. We also found some of the fastest metabolic incorporation rates measured in flying vertebrates, which support the explosive metabolic shift between rest and flight. Finally, these bats elevate circulating cortisol to 10-15 times basal values when restrained. These findings throw new light on how small tropical animal can apply several strategies to fuel dramatically fluctuating daily energetic demands, in this case including ecological specialization on a temporally unpredictable fruit resource.

95.3 OAKLEY, TH*; ELLIS, EA; HENSLEY, NM; Univ. of California, Santa Barbara; *oakley@lifesci.ucsb.edu*

Genetic Basis of Color Variation in the Bioluminescent Signals of Sea Fireflies (Cypridinidae:Ostracoda)

The origin of courtship signals may cause faster speciation and impact biodiversity. But discovering the genetic basis for diversification is usually difficult. Because aspects of the mating signals of cypridinid ostracods ("sea fireflies") are produced by a simple chemical reaction outside the body, we believe we can discover specific genetic changes that diversified those signals. Male sea fireflies court females by spitting out small boluses of mucus laced with enzyme (luciferase) and substrate (luciferin), which react to make light. Males make trains of glowing dots in different patterns depending on species. While these signals clearly diversified in pulse duration, direction, and inter-pulse distance, previous work suggested the color of luminous displays is invariant across species, and therefore unlikely to be used in mate recognition or species discrimination. However, by measuring the emission spectra of more species' luminescence, we found significant variation in color. Most strikingly, Photeros species have green-shifted spectra in both lambda max (wavelength with most photons) and FWHM (spectrum width). The lambda max of Photeros is 464 nm, while other signaling species are 458-459 nm. The FWHM of Photeros is 94-97 nm, while that of other signaling species is only 81-87 nm. We speculate the green shift could produce a more conspicuous signal by reflecting off of seagrass in the habitat of most Photeros. Furthermore, based on published mutagenesis of the luciferase of Cypridina (a non-signaling but luminous relative), we know that particular amino acid mutations change the emission spectrum in vitro. Some of the mutations that shifted Cypridina emission toward green are present naturally in Photeros. Therefore, by expressing mutated luciferases in vitro, we will be able to understand the molecular basis of evolved variation in emission spectra of sea fireflies.

43.2 OBERSKI, J.T.*; BOYER, S.L.; SHARMA, P.P.; Univ. of Wisconsin, Madison, Macalester College; *jilloberski@outlook.com*

India as a "Biotic Ferry": Systematics and Biogeography of the Harvestman Family Assamiidae

The movement of the Indian Subcontinent is a key issue in determining Gondwanan biogeographic patterns. Its position between Africa, Madagascar, and Eurasia raises questions about its geographical situation, the dates of its rifting and collision with Eurasia, and its role in dispersal events. India has been proposed as a biotic ferry which introduced African and Madagascan fauna to Asia, but it is still debated whether India was in isolation or close proximity to Southeast Asia during its journey northward. Harvestmen of the family Assamiidae (Opiliones: Laniatores) are an excellent system to address these events and vicariance hypotheses. This highly variable group of animals (2-8mm in body length) can be found throughout Africa, India, and Australasia, but is intriguingly absent from Madagascar and the Seychelles. In order to (a) test the monophyly of Assamiidae, (b) clarify the relationships between African and Asian taxa, and (c) compare the timing of continental collision and the diversification of Southeast Asian lineages, we inferred the phylogeny of the family for the first time using a multilocus dataset. We sequenced 141 terminals collected from Africa, Southeast Asia, and the Southwest Pacific for six markers known to be informative in arachnid systematics: two mitochondrial loci (16S rRNA and cytochrome *c* oxidase subunit I), and four nuclear loci (histones H3 and H4, 18S rRNA, and 28S rRNA). We performed maximum likelihood analysis in RAxML and Bayesian inference analysis in MrBayes. To distinguish between competing biogeographic hypotheses, we inferred divergence dates using BEAST and reconstructed ancestral areas using the R package BioGeoBEARS. Here we present the first molecular phylogeny of Assamiidae and a reconstruction of their biogeographic history, toward understanding the origins of Southeast Asian arachnofauna.

P3.22 ODETUNDE, AO*; CASTO, JM; Illinois State University; *aderinsola1@gmail.com*

Quit buggin' me: The effects of ectoparasite control methods on mite load and nestling phenotypes

Hematophagous mite infestations induce European starling (*Sturnus vulgaris*) nestlings to shift resource investment between immune function and growth. Additional research, designed to determine which aspects of mite infestation influence these trade-offs, has been hindered by variability in mite control methods. The literature describes several methods that vary in their efficacy for reducing ectoparasites in nests, as well as in their ectoparasite-independent effects on nestling development. This experiment assessed both the efficacy of several ectoparasite control methods for hematophagous mite reduction in starling nests, and their developmental effects on nestlings. After clutch completion, nests were inoculated with ≈ 100 Northern fowl mites to simulate an infestation. To assess mite load prior to mite control treatment, blood spots on the eggs of each nest were assessed 10 days after clutch completion. On brood day 0, nests were placed into one of four mite control treatments: control, heat, yarrow oil, and permethrin. These nest treatments were applied on brood day 0 and again on brood day 10. Nestling growth was assessed on brood days 5, 10, and 15. Blood was collected on brood day 15 to analyze hematocrit, hemoglobin and blood glucose concentrations. Preliminary analyses show no differences in growth across treatments. Nestlings in permethrin-treated nests displayed lower blood glucose concentrations, and higher hematocrit levels than nestlings in the control treatment. Nestlings in heat-treated nests had higher incidences of hematophagous mites and flies on their body compared to the other treatment groups. Results will be discussed further in light of ongoing analysis of bacterial killing capacity of plasma and assessment of post-fledging mite load in nests.

16.5 OLBERDING, JP*; DEBAN, SM; University of South Florida; *jpolberding@mail.usf.edu*

The interaction of scale and temperature in elastically powered movements

Scale and temperature are two fundamental variables that affect organismal function, including performance of musculoskeletal systems. Many small animals use elastic recoil to effectively amplify muscle power to achieve high-performance movements with power demands exceeding muscle capabilities. In larger animals elastic recoil should be less important as their muscles are better able to directly meet high power demands. Elastic recoil also reduces effects of temperature on performance. Muscle power decreases with decreasing temperature, but power amplification in elastic recoil is not affected by temperature. If the use of elastic recoil is dependent on scale, then scale and temperature will interact to influence performance. If larger animals use less elastic recoil to achieve high performance, they will also be more susceptible to changes in temperature. Alternatively, elastic recoil may be used regardless of scale because of the thermal robustness it confers. To investigate these interactions, we measured scale and temperature effects on muscle properties from Cuban tree frogs and used these data to predict jump performance. We compared predictions to values of jump performance from frogs ranging in body mass from 1-30g at 10, 20, and 30°C. Jump performance decreased significantly with decreasing temperature and larger frogs had significantly higher jump performance than smaller frogs, but temperature effects were similar for all frogs regardless of body mass. Comparisons to predicted values suggest that elastic recoil contributes similar proportions of energy to jumps in all frogs. Analyzing joint movements would allow us to determine if kinematics and kinetics of elastically powered ankle extension and muscle-powered knee and hip extension are similarly affected by temperature at all scales.

135.7 OLD, JM; Western Sydney University; *j.old@westernsydney.edu.au*

Immune system development in marsupials

Marsupials are ideal models for studying immune system development. At birth neonatal marsupials lack mature immune tissues and the ability to mount their own adaptive immune response. Newborn marsupials must therefore be reliant on their own passive immune defence strategies, or maternally-derived strategies, to survive the microbiological onslaught endured in early neonatal life prior to being able to mount their own adaptive immune response. A limited number of studies have investigated how and when pouch young marsupials first become immunocompetent. Histology has been used to describe the initial appearance of cells in the immune tissues, and the maturation of these tissues. Immunohistochemistry has enabled the pattern of appearance and distribution of some immunological markers in the developing immune tissues to be described. Real-time PCR has also been used to investigate expression levels of key immunological genes in the developing marsupial immune tissues. Despite these studies, there are many gaps in our knowledge and understanding of the strategies involved in immune protection of the neonate. This presentation will discuss current knowledge in the area of marsupial immune system development.

P3.256 OLIVER, JD*; PIERCE, SE; HAUTIER, L; Department of Ecology and Evolutionary Biology, Brown University, Providence RI, Museum of Comparative Zoology, Harvard University, Boston MA, Institut des Sciences de l'Evolution de Montpellier, Université Montpellier II, Montpellier, France; *jillian_oliver@brown.edu*

Development and patterning of xenarthrous morphology in the nine-banded armadillo

Xenarthran (armadillos, anteaters, sloths) vertebral columns are, with few notable exceptions, characterized by xenarthrae, ancillary intervertebral articulations spanning the post-diaphragmatic thoracic and lumbar regions. In recent work, we have shown that xenarthrous vertebrae constitute a discrete region of high stiffness and controlled mobility in the nine-banded armadillo vertebral column. They are thus thought to equip xenarthrans with the axial stability necessary for fossoriality, the group's hypothesized ancestral locomotor mode. Here we explore the origins of this morphology and its correlated vertebral regionalization through an investigation into the morphological development of the nine-banded armadillo (*Dasypus novemcinctus*) vertebral column. We performed 3D geometric morphometrics and clustering analyses on thoracolumbar vertebrae of sixteen fetal, post-natal, and adult armadillos, which span the course of vertebral development. We found that the adult regionalization scheme sets in late in development, with thoracolumbar vertebrae divided primarily according to xenarthrous identity, and secondarily according to thoracic or lumbar identity. The division of the thoracic region at the position of the diaphragmatic vertebra has been identified morphologically and developmentally in mice, and is reflective of *Hox*-mediated regionalization schemes across amniotes. Our results suggest that xenarthrae evolved within the prescribed *Hox*-expression boundaries common to amniotes, thus facilitating the region's specialization towards fossoriality in the ancestral xenarthran.

131.4 OLMI, H.D.*; DARNELL, M.Z.; University of Southern Mississippi; *helen.olmi@usm.edu*

Migratory Movements and Fishing Mortality of the Louisiana Blue Crab Spawning Stock

Blue crabs, *Callinectes sapidus*, support Louisiana's third largest commercial fishery. Louisiana has led the nation in blue crab landings for 7 of the last 10 years. Landings in 2014 totaled 39.4 million pounds for a dockside value of $61 million. Although blue crabs are not currently overfished, fishery-independent estimates of abundance have indicated a decline in recent years and are now below long-term averages as well as target reference points. Management efforts for the fishery have been hindered by an incomplete knowledge of the migration patterns and fishing mortality of Louisiana blue crabs. In March 2016, we began a mark-recapture study to examine these trends in the Terrebonne and Pontchartrain basins. In collaboration with local fishermen, we have tagged 2,500 crabs, with a final target number of 6,000 female blue crabs from multiple salinity zones. Tags (1 x 2 in.) lay flat across the carapace and are secured by steel wire wrapped around the lateral spines. Recapture data have been obtained from commercial and recreational crabbers and shrimpers, state fisheries agencies, and the public. In general, tagged female blue crabs moved seaward, consistent with our understanding of the spawning migration from studies on the Atlantic Coast. Recapture rates are also being used to assess spatial and temporal patterns in fishing mortality. Finally, recently molted females from each tagging area are collected, and their sperm stores examined to determine if heavier fishing of males affects sperm abundance and thus, reproductive success. This information, combined with tag-recapture results, will be directly applicable to Louisiana blue crab management plans, stock assessments, and will ensure the continued sustainability of the Louisiana blue crab fishery.

117.7 OLSEN, AM*; CAMP, AL; BRAINERD, EL; Brown University; *aarolsen@gmail.com*
Balancing complexity and error in kinematic models: fitting 2D and 3D four-bar linkage models to the opercular mechanism of largemouth bass (Micropterus salmoides)
The heads of ray-finned fishes contain numerous mobile skeletal elements, interconnected as mechanical chains that can transmit muscle forces to multiple and distant skeletal elements. A traditional model for these skeletal elements is the planar 4-bar linkage. While planar 4-bar models can accurately predict the motion of certain mechanisms in fish skulls, previous work found this model of the opercular mechanism overestimates jaw depression in largemouth bass by 50%. It is unclear what simplifying assumptions of the planar 4-bar contribute to this poor fit. In this study we combine *in vivo* XROMM data acquired during suction feeding in largemouth bass (*Micropterus salmoides*) with kinematic simulation using the R package 'linkR' to determine how assumptions of constant link lengths and planar motion affect model accuracy. We find changes in the link length of the 4-bar to be greatest in the interoperculum link, which lengthens by at least 5% at peak gape, due, in part, to stretching of the interopercular-mandibular ligament. We also find substantial deviations in the rotations of the operculum and lower jaw from a single, best-fit axis of rotation. In a comparison of 6 linkage models of varying complexity, ranging from 13 to 259 parameters, we find a distinct increase in error in transitioning from a 2D to 3D 4-bar model. A 2D 4-bar model has a mean error of 19 deg (1.9 mm) while a 3D 4-bar, requiring 6 additional parameters, has a mean error of 5.3 deg (0.8 mm). Thus, a 3D 4-bar linkage balances substantially improved accuracy with the addition of relatively few parameters, making it a useful model for understanding and comparing functional diversity in the skulls of fishes. This work was funded by NSF DBI-1612230.

117.2 OLSON, RA*; MONTUELLE, SJ; WILLIAMS, SH; Ohio University; *ro603313@ohio.edu*
Stereotypy and flexibility of jaw movements during feeding in pigs
Among mammals, omnivores may be particularly well-suited for responding to high levels of variation in food properties due to their varied diet. In pigs, a quintessential mammalian omnivore, the relatively unconstrained temporomandibular joint suggests that jaw movements may facilitate a flexible response to changes in food properties when feeding on different foods. Previous work has shown comparatively high levels of variability in the temporal aspects of chewing on different foods in pigs at the intra-cycle level (i.e., cycle phases), with corresponding low levels of variability in total gape cycle duration. Here, we use X-ray Reconstruction Of Moving Morphology (XROMM) to examine the spatial aspect of chewing kinematics in pigs chewing on four different foods: pellets, apples, almonds, and carrots. Variability in feeding movements is evaluated at two levels: 1) within each food type across four individuals (i.e., stereotypy) and 2) across food types (i.e., flexibility). Results indicate that condylar and jaw movements are altered in response to different foods. Condylar protraction and retraction show low variability during almond and carrot chewing, but this is not the case for mediolateral translations, which are fairly comparable across all foods. Comparisons of patterns of variability in feeding movements, as well as the analysis of the feeding movements themselves, will provide valuable insights into the ways in which organisms deal with changes in external stimuli and the adaptability and response of sensorimotor systems.

65.4 ONTHANK, KL; ONTHANK, Kirt; Walla Walla University; *Kirt.Onthank@wallawalla.edu*
Late to the Party or Noticing the Wallflower? Story of an Apparent Deep Water Octopus Living in Shallow Water
As we are currently experiencing rapid shifts in organism geographic distribution across the planet, how do we know if a new geographic record for an organism in an under-sampled region represents a new immigrant or newly-discovered native population? In August 2014, octopuses previously unknown in shallow water were discovered in less than 11 m of water in Burrows Bay, near Puget Sound, Washington. Over the subsequent two years 31 of these octopuses have been observed in that bay. These octopuses have proportionally large eyes, do not alter skin texture or change color, have a fold of skin around the lateral margin of the mantle, and lack an ink sac. These characteristics are common among deep-water octopuses and superficially these octopuses appear to be *Muusoctopus leioderma*, a species known locally but normally found deeper than 70 m, and most commonly between 300 and 500 m. Morphological and genetic evidence, however, have brought this identification into question. These observations represent the shallowest records for the species *M. leioderma*, and for this genus. These sightings also represent the first *in-situ* observations of the behavior of this strongly nocturnal species, which includes burrowing into fine sediment. A remaining question concerning the recent discovery of these octopuses is whether this population is endemic to Burrows Bay and simply overlooked, or if these octopuses have recently moved into shallow water.

S8.9 ORR, T.J.*; GARLAND, T., Jr.; Dept. of Biology, Univ. of Utah, Dept. of Biology, Univ. of California, Riverside; *teri.orr@utah.edu*
Complex reproductive traits and whole-organism performance
Arnold's (1983) path-analytic paradigm, considering "morphology, performance, and fitness," has been elaborated in several ways. For example, current versions (e.g. Fig 1 in Storz et al. 2015, Am J Physiol 309:R197) recognize the level of "behavior" (including aspects of motivation) as a filter between performance abilities (only measurable if motivation is maximal) and fitness components. Performance abilities constrain behavior, but behavioral choices may shield performance from selection. Conceptual and empirical issues remain, such as the extent to which individual variation in lower-level subordinate traits (e.g. circulating hormone concentrations) might directly affect behavior, growth rates, sexual maturation, etc., rather than having effects only through paths involving some aspect of performance. Moreover, empirical studies have yet to encompass more than a few possible paths in a given system, in part because life-history researchers rarely communicate with those focused on performance. Most life-history studies ponder trade-offs associated with reproductive effort, studies of locomotor performance (e.g. maximal sprint speed) rarely consider trade-offs with reproduction. This is surprising because both life history (e.g. clutch size) and locomotor performance traits require allocation of energy and other resources, so trade-offs between these trait types are expected. These perspectives and cultures could be bridged by a focus on the ability of organisms to perform components of reproductive biology (e.g. maximal lactation studied in animals maximally "motivated" by manipulation of litter size or endocrine function). Alternatively, one could study impacts of reproduction on performance, as when bats and live-bearing fishes lose maneuverability during gestation.

70.5 ORSBON, CP*; GIDMARK, NJ; ROSS, CF; University of Chicago, Knox College; *orsbon@uchicago.edu*

Form and Function Dynamics of the Primate Hyoid Apparatus: The Relationship Between Hyoid Posture and Muscle Behavior.

The link between hyoid posture and muscle behavior may be dynamic across the many vital behaviors that involve the hyoid. Previous research has shown that, in primates, hyoid translations during swallows are larger than those of other feeding behaviors (e.g., chewing), but whether and how such translations relate to muscle function is unknown. We integrated XROMM, contrast-enhanced CT, and EMG to examine the relationship between *in vivo* muscle length changes, line of action, and activity patterns in two hyoid muscles (mylohyoid and geniohyoid) during 50+ chewing and swallowing cycles in *Macaca mulatta*. Different hyoid postures had different muscle orientations, particularly in mylohyoid during swallows. Anteroposterior displacement and velocity of the hyoid can be accounted for by changes in geniohyoid length and velocity alone in both chews and swallows. However, superoinferior displacement and velocity of the hyoid cannot be accounted for by mylohyoid length and velocity alone in swallows. Additionally, there is a stronger correlation between mylohyoid fiber angle (i.e., fiber rotation) and hyoid superoinferior position during swallows than chews. Timing of high hyoid elevation velocity with lower mylohyoid shortening velocity corresponds with high mylohyoid activation, further suggesting that fiber rotation is functionally important in swallows. The results suggest that geniohyoid function is robust to changes in hyoid posture while mylohyoid function is more dynamic. Muscles with simple fiber architecture may be able to generate different behaviors through a more complex interaction of shortening and fiber rotation.

P1.21 ORTEGA, J. M.*; TOTH, C. M.; Providence College; *jortega@friars.providence.edu*

Analysis of Neuroinflammatory Genes using Human Cerebral Organoids

Stem cells have the unique potential to differentiate into tissues with specific functional attributes. One of the major questions in developmental biology is to understand what environmental and genetic factors play a role in affecting the fate of stem cell lines. Advances in human stem cell biology have made it possible to grow small clusters of cells, or 'organoids' that resemble human physiology of brains in vitro. Our research focuses on growing three-dimensional cultures to model developing nervous systems using induced pluripotent cells (iPSCs). These 3D cultures are referred to as cerebral organoids. The goal of this research is to study gene expression changes in inflammatory genes. Induced human pluripotent stem cells will be utilized to grow cerebral organoids. The organoids will be treated with poly (I+C) +/- indoxyl-3-sulfate (iS3) in order to induce an inflammatory response. Gene expression analysis will be used to study the effects of the inducers. Inflammatory genes IL6, SAA1, AHR, and NOS1, commonly associated with multiple sclerosis and encephalitis, will be specifically examined in this research.

S7.7 ORTEGA-HERNANDEZ, J*; JANSSEN, R; BUDD, GE; Univ. of Cambridge, Cambridge, Uppsala Univ. Uppsala; *jo314@cam.ac.uk*

Origin and Evolution of the Panarthropod Head - a Deep Time Perspective

The panarthropod head represents a complex body region that has evolved through the integration and functional specialization of the anterior appendage-bearing segments. Advances in the developmental biology of diverse extant organisms have led to a substantial clarity regarding the relationships of segmental homology between Onychophora, Tardigrada, and Euarthropoda. The improved understanding of the segmental organization in panarthropods offers a novel perspective for interpreting the Cambrian fossil record of these successful animals. A combined palaeobiological and developmental approach to the study of the panarthropod head through deep time leads to propose a consensus hypothesis for the intricate evolutionary history of this tagma. The contribution of exceptionally preserved brains in Cambrian fossils - together with the recognition of segmentally informative morphological landmarks - illuminate the character polarity for major anatomical features. The euarthropod stem-lineage provides a detailed view of the step-wise acquisition of critical characters leading to the formation of a multiappendicular head formed by the fusion of several segments, such as the transformation of the ancestral protocerebral limb pair into the labrum, following the postero-ventral migration of the mouth opening. Stem-group onychophorans demonstrate an independent ventral migration of the mouth, as well as the differentiation of the deutocerebral limbs as expressed in extant representatives. The anterior organization of crown-group Tardigrada retains several ancestral features, such as an anterior-facing mouth and one-segmented head. A proposed model aims to clarify contentiuous issues on the evolution of the panarthropod head, and lays the foundation from which to further address this complex subject in the future.

2.7 ORTEGA-JIMÉNEZ, VM*; MARTÍN-ALCÁNTARA, A; FERNÁNDEZ-FERIA, R; DUDLEY, R; Univ. of California, Berkeley, Unv. of Málaga, Spain; *ornithopterus@gmail.com*

Autorotation Performance of Animal wings

Many winged seeds autorotate and produce aerodynamic forces to effectively reduce their rate of descent. Isolated animal wings, however, have not yet been studied in this regard. We report that wings from Anna's Hummingbirds and ten species of insects can spin around their center of mass and achieve descent speeds in a vertical wind tunnel similar to those reported for winged seeds. Sequential feather removal from hummingbird wings showed no effect on descent speed when the secondaries were removed, but substantially improved performance when only the last five primaries were present. Even wings with only the outer primary present showed stable autorotation, albeit with degraded performance. Manipulative experiments on hummingbird wings loaded at their base with approximately half of the bird's body mass descended only twice as fast as the unloaded wings and rotated at frequencies similar than those exhibited by hovering hummingbirds. We show that whole dead insects can also autorotate depending on their fixed wing posture. Finally, we present a scaling law for aerodynamic performance during autorotation of animal wings.

123.6 ORTEGA-JIMENEZ, VM; ARRIAGA-RAMIREZ, S*; DUDLEY, R; Univ. of California, Berkeley, Univ. of California, Davis; *sarriaga@ucdavis.edu*

Meniscus-climbing by Thrips in Varied Viscous Solutions

Meniscus climbing has been described and modelled for aquatic and semi-aquatic insects, but it had never been observed in small flying insects despite them often becoming trapped on water surfaces. We report that thrips (Order Thysanoptera) can ascend or descend a water meniscus by arching or straightening their bodies respectively. Using sucrose solutions with different concentrations we demonstrate that thrips' climbing speed reduces with viscosity. The meniscus climbing abilities shown by thrips suggest that escaping from water surfaces may be a regular surviving strategy for small flying insects.

116.5 ORTON, R.O*; MCBRAYER, L.D; Georgia Southern University, Georgia Southern University ; *ro00606@georgiasouthern.edu*

Predation and Color Polymorphism in a Fragmented Landscape

Organismal phenotypes can result from a subtle balance between local selective pressures and dispersal across ecological transition zones. A commonly studied example is the influence of predation and substrate heterogeneity on color polymorphism. The Florida scrub lizard (*Sceloporus woodi*) inhabits longleaf pine and sand pine scrub habitats, which contrast in predator abundance and substrate type, within the Ocala National Forest. Using clay models, we measured relative differences in predation rate between the two habitat types and found that predation rate is significantly greater in sand pine scrub. We then quantified differences in dorsal color and reflectance of *S. woodi* and their degree of substrate matching between habitats using calibrated digital photographs and an Ocean Optics flame spectrometer. Individuals from sand pine scrub, where there is an abundance of open sand, tended to have a higher reflectance than individuals from longleaf pine. Our goal is to combine objective measures of color with relative predation rate to study the role of selective pressures on the process of adaptive divergence. Recent availability of microsatellite data may additionally allow for the assessment of how reduced gene flow drives local adaptation.

P1.150 OSMANI, M; University of North Florida ; *morsal.osmani@gmail.com*

Breast is Best: Exploring the Differential Effects of Breast Milk versus Formula on the Growth of Neonate Gut Bacteria

Breast milk has been shown to have beneficial effects toward signal species that signify good infant gut health. One of these species is *Bifidobacterium infantis*, which is among the predominant species in the guts of breast-fed infants. We also examined two other bacterial species, *Enterococcus faecalis*, which is found in the guts of both breastfed and formula-fed infants, and *Staphylococcus aureus*, the abundance of which was determined to have a positive correlation with the total human milk oligosaccharide (HMO) content. HMOs, the third most abundant component in human milk, has been shown to have prebiotic effects on *B. infantis*. However, it has also been shown that *E. faecalis* is a poor metabolizer of HMOs, while there are relatively few pieces of literature discussing the ability of *S. aureus* to metabolize HMOs. We examined the effects of breast milk versus formula on the growth of these three species. Cultures were grown in Hungate tubes in order to simulate the anaerobic conditions of the human gut over an 8-hr time course with their turbidity measured every hour. There was a statistically significant difference ($p < 0.05$) in *B. infantis* growth between the breast milk and the formula media, with more growth observed in the breast milk media. In contrast, there was no significant difference ($p > 0.05$) in *E. faecalis* growth between the two media. Interestingly, significant difference ($p<0.05$) was found in *S. aureus* growth between the two media, with more growth found in the breast milk media, but only after hour 5. Moving forward, mothers should try to breastfeed their infants and formula production should begin to include HMOs in order to promote optimal infant health.

98.4 OTHAYOTH, RS*; XUAN, QH; LI, C; Johns Hopkins University; *ratan@jhu.edu*

Leg vibrations help cockroaches self-right using wings

When flipped over, cockroaches can use their wings to push against the ground to self-right dynamically. In this process, it often takes an animal multiple failed maneuvers before it eventually rights. However, it is not clear what governs this seemingly random locomotor transition. Here, we hypothesize that vibrations induced by leg flailing help achieve successful righting. To test this hypothesis, we directly modified leg vibrations in the discoid cockroach (*Blaberus discoidalis*) by attaching weights (1.5 times leg mass) to hind legs and challenged the animal to self-right on a flat, rigid surface. We discovered that an increase in leg vibrations increased righting probability from 45 ± 8 % (N = 30 animals, n = 150 trials) to 75 ± 7 % (N = 30, n = 150) (P < 0.0001, repeated-measures ANOVA) and reduced righting time from 4.0 ± 3.5 s to 2.8 ± 2.8 s (P = 0.0049). Upon removal of added leg mass (N = 30, n = 150), righting probability and righting time recovered to 28 ± 7 % and 4.4 ± 3.5 s. To further confirm our hypothesis, we created and tested a cockroach-inspired winged self-righting robot with continuously variable vibrations, and made similar observations over a broad range of wing opening magnitudes. To begin to understand our observations, we developed a locomotion energy landscape model, and found that the energy fluctuations due to vibrations were comparable to the potential energy barriers required to transition from a metastable overturned orientation to an upright orientation. Our study supports the plausibility of locomotion energy landscapes for understanding locomotor transitions, and highlights the need for further stochastic modeling to capture the uncertain nature of when maneuvers result in successful righting. Our study also provides inspirations for legged robots to co-opt leg oscillations to assist locomotor transitions.

99.8 OTTO, A. W.*; ROSENTHAL, M. F.; ELIAS, D. O.; HATTON, R. L.; Oregon State Univ., Univ. of California, Berkeley; *Ross.Hatton@oregonstate.edu*

Vibrations in a Spider's Web

Due to their poor eyesight, spiders rely on web vibrations for situational awareness. In particular, web-borne vibrations are used to determine the location of prey, predators, and potential mates. The influence of web geometry and composition on web vibrations is important for understanding spider's behavior and ecology. Studies in web vibrations have experimentally measured the frequency response of web geometries by removing threads from existing webs. The full influence of web structure and tension distribution on vibration transmission; however, has not been addressed in prior work. Through a combination of scaled-up physical models (on a 1.2m artificial web constructed of parachute and bungee cord), computer simulations, and measurements on real spider webs, we have identified features in webs' vibration responses that indicate the source location of disturbances applied to the web. In particular, the vibration responses *above* the webs' first fundamental frequencies contain strong signatures corresponding to the range and direction of the disturbance. These results highlight that vibrations in webs (and other continuous media) carry information not only by faithfully transmitting signals from the source to a single receptor, but also in the differences between how the signals are transmitted to multiple receptors; we suggest that this extra information path should be accounted for in studies of organisms' behavioral response to vibratory stimuli.

61.8 OUFIERO, CE; Towson Univ.; *coufiero@towson.edu*

Changes in the functional morphology of a praying mantis feeding strike across ontogeny and between the sexes.

Sexual dimorphism in morphological traits, resulting from male-male competition or fecundity selection on females, has been well documented in many species. These differences between the sexes in morphology may have functional consequences, affecting the performance of either sex. While the dimorphism between the sexes is most often expressed in the adults, few studies have quantified whether the dimorphism of form and function is persistent throughout development. The goal of this study was to determine the difference in body size, foreleg size and kinematics of the feeding strike of a praying mantis throughout ontogeny and between the sexes. The feeding strikes of 8 ghost praying mantises (*Phyllocrania paradoxa*) from instar 4 (juveniles) to instar 8 (adults) were filmed at 1000 Hz. Several points were digitized on the mantises to obtain a set of angular and linear kinematics associated with the strike; as well as body and foreleg size. Using mixed models, I assessed the affect of instar, sex, prey position and their interactions on body and foreleg size, and principal components that characterize the angular and linear movements of the foreleg. I found similar trajectories of growth and kinematics between the sexes in juveniles, with angular kinematics decreasing and linear kinematics increasing. However, I found significant differences in foreleg size and linear kinematics in adults, with females exhibiting proportionally longer forelegs that are moved more and faster than males. These results suggest the differential growth of the foreleg between the sexes alters the biomechanics of the feeding strike, allowing for increasing linear kinematics despite decreasing angular kinematics during ontogeny. These patterns of form and function will be discussed in relation to life history evolution.

62.6 OUYANG, JQ *; DE JONG, M; MATSON, KD; HAUSSMANN, MF; MEERLO, P; VISSER, ME; SPOELSTRA, K; University of Nevada, Reno; *jqouyang@gmail.com*

Restless roosts: light pollution affects physiology and behavior in a free-living bird

The natural nighttime environment is increasingly illuminated by electric lighting, which causes a concurrent increase of novel challenges for wildlife. Light pollution is associated with changes in circadian, reproductive, and social behavior, but we currently lack knowledge on whether these organisms also suffer from health problems. We used a worldwide unique network of field sites artificially illuminated with white, green, and red light to monitor nighttime activity of adult great tits, Parus major, and related their nighttime behavior to within-individual changes in physiological measures. Individuals roosting in the white light treatment had higher activity and corticosterone concentrations than in the other treatments. We found that oxalic acid, with low concentrations as an indicator of sleep debt, decreased from March to May for individuals with higher activity at night. Our results indicate that white light at night increases nighttime activity levels, sleep debt, and affects hormone levels in a free-living songbird.

P1.52 OWEN, PC*; MUSTAFA, AB; STRINGFIELD, TW; University of Cincinnati; *patrick.owen@uc.edu*

Examination of Sexually Dimorphic and Aposematic Color Patches of Frogs for Carotenoid Pigments

Males of many species of animals use bright color patches as visual signals. If sexually dimorphic, these patches are typically found in males that use them to attract mates or to ward off rivals. Color patches used in a mating context may contain costly pigments such as carotenoids that allow them to function as indicators of male quality. Other types of color patches may function as aposematic visual signals to ward off predators, and these may contain less costly pigments that can be synthesized by the animal rather than having to be obtained through the diet like carotenoids. We used acidified pyridine extraction followed by nonpolar solvent transfer and spectrophotometry to determine the presence or absence of carotenoids in color patches of two species of anuran amphibians. Males of both Green Frogs (*Lithobates clamitans*) and Cope's Gray Treefrogs (*Hyla chrysoscelis*) have pigmented throat patches, although only Green Frogs have obvious yellow coloration in the throat patch. We did not detect the presence of carotenoids in throat patches of males of either species, although carotenoids were detected in the dorsal skin of Green Frogs. The male Green Frogs that were available for analysis had relatively weakly pigmented throat patches, possibly below our detection ability for carotenoids. Both sexes of Cope's Gray Treefrogs possess yellow leg patches that presumably are displayed in an aposematic context. We isolated yellow pigment from these leg patches in the extraction procedure. However, the pigment did not subsequently transfer to the nonpolar solvent, indicating it is not a carotenoid. In future work, we will determine whether other pigments such as melanins or pteridines may be responsible for the yellow color of these leg patches.

72.4 OWEN, DAS*; SHERIFF, MJ; HEPPNER, J; GERKE, H; ENSMINGER, DC; MACLEOD, KJ; LANGKILDE, T; Pennsylvania State University, Texas A&M University; *dasowen27@gmail.com*

Hot and Bothered: Maternal Stress Alters Thermal Sensitivity of Metabolic Rate in Lizard Embryos

Recently in vertebrates, maternally-derived stress hormones, glucocorticoids, have been shown as a significant inducer of transgenerational phenotypic plasticity. Offspring phenotypic responses are often interpreted as unavoidable negative side effects of maternal stress. Growing evidence supports the adaptive hypothesis for maternal stress whereby phenotypic responses in offspring may be adaptively matched to the local environment. While many studies have examined how maternal stress has influenced the post-natal trails of offspring, few studies have addressed the effects of maternal stress on the pre-natal life stage. We tested the hypothesis that stressed female eastern fence lizards (Sceloporus undulatus) have embryos that have higher metabolic rates (i.e. heart rates). This should result in faster growth, and decrease the amount of time the embryos spend in their most vulnerable stage of life (egg stage). We found that embryos of stressed mothers had greater heart rates at higher temperatures, but similar heart rates at lower temperatures, compared to embryos of control mothers. Additionally, embryo heart rate was higher in larger eggs and decreased through the day. Thus, maternal stress appears to alter the pre-natal physiology of fence lizards. This likely would result in faster developmental rates, earlier hatching, and larger body size of offspring from maternally stressed females. These consequences of maternal stress could be adaptive in high stress environments, increasing fitness of populations faced with increased predation, heat stress, and/or competition.

113.6 OWERKOWICZ, T.*; IVY, C.M.; SCOTT, G.R.; CSUSB, McMaster; *towerkow@csusb.edu*

Respiratory turbinate surface area is not affected by adaptation to high-altitude hypoxia in deer mice

Respiratory turbinates - maxillo- and nasoturbinal bones in the nasal cavity of mammals - have been proposed as anatomic correlates of endothermy in mammals. By substantially augmenting the epithelial surface area of the nasal cavity, respiratory turbinates help and reduce heat and water loss in expired air. Respiratory turbinate surface area (RTSA) has been shown to be a strong predictor of field metabolic rate (FMR) in mammals, seemingly in support of the endothermy hypothesis. An alternative hypothesis, however, proposes that respiratory turbinates evolved in mammalian ancestors in response to falling atmospheric oxygen level in the Late Triassic. If the latter is true, we would predict that RTSA is higher in contemporary mammals adapted to high-altitude hypoxia. Deer mice (*Peromyscus maniculatus*) from lowland and highland populations were maintained in laboratory conditions under normobaric normoxia and hypobaric hypoxia, respectively. Following ventilatory and respiratory measurements in the whole animal, the nasal cavities (n=5) were analysed histologically. RTSA correlated with body mass (17-26g), but did not differ between treatment groups. RTSA did not show a significant correlation with breathing rate, tidal volume, or minute ventilation. Further, RTSA was not a good predictor of metabolic or water loss rates. This suggests that RTSA does not match intraspecific variation in respiratory parameters in a rodent species with the widest altitudinal distribution among North American mammals. As such, our results do not lend support to the hypothesis that respiratory turbinates evolved in response to a bout of global hypoxia over 200 million years ago. Whether other factors may have played a role in sculpting the intranasal morphology of mammals is yet to be determined.

51.7 OYEN, K/J*; HERNDON, J/D; STRANGE, J/P; LOZIER, J/D; DILLON, M/D; Univ. of Wyoming, Utah State Univ., Univ. of Alabama; *koyen@uwyo.edu*

Common garden experiments reveal local adaptation in critical thermal limits of bumblebees (Apidae, Bombus) over short geographic distances

The extreme cold and hot temperatures that organisms can tolerate - critical thermal minimum (CTmin) and maximum (CTmax) - are often tightly correlated to geographic distributions of diverse species. Critical thermal limits can therefore provide key mechanistic links between organism physiology and ecology, facilitating predictions of range and phenology shifts in response to climate change. Shifts in distributions of bumblebees (genus *Bombus*) are likely driven by changing climate, but their critical thermal limits have rarely been measured. Bumblebee species are broadly distributed across latitudinal and altitudinal gradients; local populations must therefore contend with strongly divergent climates, and may do so by having similarly divergent critical thermal limits. We tested this prediction using the widely-distributed Western North American bumblebee, *Bombus vosnesenskii*. We initiated nests from queens collected at four sites distributed across altitude (sea level to 2100m) and latitude (southern CA to Oregon), reared nests in common garden conditions and measured critical thermal limits of worker bumblebees. CTmin decreased strongly with altitude, with bees reared from high altitude queens tolerant of temperatures ~5 C colder than those from low altitude, despite these populations being separated by less than 100 km and no obvious barriers to gene flow. CTmin decreased less with latitude (as expected given climatic differences between these sites). Similarly, CTmax varied little across latitude, but was ~2 C hotter for bees reared from high altitude queens. This strong evidence for local adaptation in bumblebee thermal tolerance provides a key mechanistic link between thermal physiology and geographic distribution of these critical pollinators.

123.8 OZKAN AYDIN, Y.*; RIESER , J. M.; GONG, C.; MICHEL, K.; RANKIN, J.; NICIEZA, A.G.; HUTCHINSON, J.R.; CHOSET, H.; GOLDMAN, D.I.; Georgia Tech, Carnegie Mellon, The Royal Veterinary College, Universidad de Oviedo, Carnegie Mellon; *yasemin.ozkanaydin@physics.gatech.edu*

Coordinated Body Bending Improves Performance of a Salamander-like Robot

Mudskippers and salamanders can both swim and navigate outside of the water. We wish to understand how limbs and body morphology contribute to performance, particularly in the evolution of animals that use multiple modes of locomotion. Here we study a fire salamander (*S. salamandra*) to understand the coordinated movement between the flexible body and limbs. Experiments (10 adults, 5 trials each, varying inclines and presence/absence of sandy surface) revealed that salamanders propelled themselves using diagonal leg pairs and body undulation. To investigate mechanisms governing effective locomotion, we built a robophysical model and tested its performance on hard ground (HG) and yielding granular media (GM) of poppy seeds of different inclinations. Our servo-driven robot (430 g, 38 cm long) has four limbs, a flexible trunk, and an active tail. Each limb has two motors to control vertical position and step size of limb. A joint in the middle of the body controls horizontal bending. We assessed performance of the robot by measuring body displacement over a few limb cycles. On HG at 0^o and 10^o slopes, the robot performed well; feet did not slip and body bending increased step length (SL) by ~50% (on level) and ~1% (on 10^o slopes). On GM, the robot's SL decreased by ~40% (on level) and ~80% (on 10^o slopes) relative to that on HG due to limb slip. Back bending restored performance on GM, leading to SLs only ~20% (on level) and ~25% (on inclined) less than those on HG. A geometric mechanics model revealed that on level GM media body bending was most beneficial when phase offset 180 degrees from leg movements.

P3.157 P KARKI, N*; COLOMBO, RE; GAINES, K; MAIA, A; Eastern Illinois University, Charleston; *nparajuleekarki@eiu.edu*
Effects of 17β estradiol in the metabolism and morphology of sunfish species
Fish habitats are increasingly contaminated with estrogenic compounds, including 17β estradiol (E2). E2 causes adverse effects on the reproductive system of male fish; however, the effects of E2 on other aspects of fish metabolism are not well known. Our objective is to evaluate the effects of E2 exposure on the basal and stressed metabolic rate and morphological changes in body shapes of sunfish. Fish were held individually in ten gallon tanks under two treatments with varying estradiol concentrations (40 and 80 ng/l) and one control treatment (no E2). The duration of E2 exposure was 21 days, with E2 being replenished every week based on its half-life. Basal and maximum aerobic scopes were measured using close respirometry and a chase protocol at the beginning and at the end of the experiment. Lateral pictures of the fish were also taken at these two time points. Our working hypotheses are that (1) fish subjected to E2 exposure would experience stress and thus increased oxygen consumption, and (2) male dimorphic characters would become less noticeable in exposed fish. Our results show that in the control group the basal metabolic rate decreased after 21 days; whereas in the estradiol exposed groups, it did not. Although maximum oxygen consumption did not alter, the aerobic scope also increased in control individuals but not in exposed individuals. We observed the reduction in operculum size and decrease in head size in exposed individuals but not in the control. Contrary to our hypothesis, aerobic scope increased only in control males which could be related to aggressive male displays and higher allocation of resources to gonad development. E2 exposure caused some morphological changes in male related characters in sunfish which eroded male dimorphic characters. Our research highlights negative effects of estradiol that are more widespread than simple gonadal alterations.

P1.15 PAI, A; SHARIF, W; MCGINNIS, G; KOVACS, J*; POWOLNY, A; Spelman College, Morehouse College; *jkovacs@spelman.edu*
Personalization of the curriculum: A novel strategy to retain diverse students
U.S. currently faces several problems which are eroding the country's expertise in scientific research and innovation. A major problem is low youth interest in pursuing careers in science, technology, engineering, and mathematics (STEM disciplines). These phenomena are more evident among traditionally underrepresented minorities, especially African Americans. Students from underrepresented groups often feel alienated by the abstract nature of science curricula. A vast body of literature points to the effectiveness of pedagogical techniques that are active, investigative, collaborative, integrative, and applied/relevant in retaining students (particularly underrepresented minorities) in the science pipeline. In this study, we ask if personalizing the educational experience, thereby making it even more relevant to students, can further increase retention in science and improve knowledge of, and interest in sciences? We will present data from our classes in introductory biology in which have personalized the curriculum by means of modern genetic technologies. Introductory Biology students at two historically black institutions (Morehouse College and Spelman College) will be exposed to a short 2-4 week long module on genes and genealogy in fall 2016. Students will learn the basics of genetics and evolution via an exploration of their own DNA (from genetic testing kits) or fake DNA sequence of an online "avatar". This exercise will incite student investigation of their personal history using the tools of biology (genetics and DNA) and history (personal genealogy and family history). Starting with the "study of me," students will be introduced to the principles of inheritance, modern genetics, and the evolutionary process.

P2.92 PAITZ, RT*; GILLARD, MA; BOWDEN, RM; Illinois State University; *rpaitz@ilstu.edu*
Do moms put enzymes into eggs to protect embryos from exposure to environmental chemicals?
The number of human-made chemicals present in the environment has increased dramatically in the past century, and while we are only beginning to appreciate how these compounds affect developing organisms, the reality is that vertebrate eggs have always developed in environments that contained natural chemicals. If any of these chemicals were to disrupt embryonic development, this should select for a mechanism to prevent embryonic exposure. Fortunately, most vertebrates possess a suite of enzymes that confer some ability to metabolize environmental chemicals, whether natural or human-made. Here we present evidence that red-eared slider turtle eggs possess enzymes that are capable of metabolizing a common human-made chemical, bisphenol-A (BPA), as it passes from the external environment through the eggshell. Importantly, metabolism does not take place if BPA is injected directly into the yolk, indicating that these enzymes are located in or near outer membranes, and as metabolism is taking place immediately after oviposition, it suggests these enzymes are of maternal origin. Given the recent origin of BPA, these enzymes likely represent a general mechanism for modulating embryonic exposure to a variety of environmental chemicals, and not BPA specifically. These results have important implications for studies of environmental chemicals, as the ability of embryos to respond to exposure to chemicals from outside the egg may be vastly different than exposure to maternally derived chemicals transferred via the yolk. Additionally, variation in maternal enzyme levels, and any contributions to offspring, may provide an opportunity for populations to rapidly respond to exposure to a novel endocrine disruptor.

P1.102 PAK, C*; PARK, J; JOHNSON, D; ANDERSON, TK; STAHLSCHMIDT, ZR; Univ. of the Pacific, USDA-ARS; *zstahlschmidt@pacific.edu*
Developmental plasticity of traits and multi-trait interactions in a wing-dimorphic cricket
Animals vary in a range of important traits related to fitness, such as growth, reproduction, and self-maintenance. These individual traits may be developmentally plastic and, thus, irreversibly determined by the environment in which an animal develops. Yet, the developmental plasticity of relationships *among* traits is less understood. Therefore, we manipulated nutrient density throughout development and measured investment into growth (adult body size and mass, and developmental rate), reproduction (gonad mass and head width [a proxy for intra-sexual combat success in males]), and self-maintenance (activity of phenoloxidase [PO], an important immune enzyme) in two morphs of sand field crickets (*Gryllus firmus*) constrained by a flight-fecundity tradeoff. We reared crickets on either a low-density diet (10% cat food and 90% bran) or a high-density diet (90% cat food and 10% bran) throughout development. At adulthood, we measured aspects of morphology, sampled hemolymph for subsequent PO assays, and stored animals at -20°C prior to removing and weighing gonads. In addition to traditional methods of analysis (e.g., multivariate analysis of variance, MANOVA), we used quantitative network topology metrics to examine and describe the relationships among the independent and interactive effects of sex, wing morphology, and developmental environment on growth, reproduction, and self-maintenance. A high-density diet and long-wing morphology prolonged development, and females were larger, heavier, and in better body condition while males had wider heads (MANOVA). We will present further results on investment into reproduction and self-maintenance, and on network metrics that quantify the developmental plasticity of multi-trait interactions.

P1.87 PALECANDA , S*; CHAN, A; PORTER, ML; University of Hawaii, at Manoa ; *spalecan@hawaii.edu*
Shifts in Opsin Expression During the Larval to Adult Transition in Pullosquilla thomassini (Crustacea, Stomatopoda)
Stomatopods possess one of the most intricate visual systems in nature. Their stalked eyes move independently and have multiple spectral and polarization channels, with some species possessing up to 16 spectrally unique photoreceptors and 33 opsin proteins. Amazingly the complex retina responsible for these abilities forms over a short period, sometimes within a few days, during the last phase of larval development. Growth of the adult retina is accompanied by a gradual degeneration of the larval retina. Very little is known about visual systems in larval or embryonic stomatopods despite the fact that retinas begin to form early in embryonic development. Using transcriptomic analyses, we aim to identify the opsin proteins expressed at embryonic, larval, and adult developmental stages of *Pullosquilla thomassini*, a species which possesses the most complex of stomatopod eye types, and use this information to describe how the stomatopod sensory system develops. Transcriptomes of retinal tissue from four embryonic stages, a larval stage, and an adult have been assembled using trinity. Preliminary data suggests that adult *P. thomassini* possess ten middle-wavelength sensitive and six long wavelength sensitive opsins. In addition to opsins we have also found evidence for the expression of other phototransduction genes including Gqα, TRP channels, and arrestin proteins. With this information we are able to produce a complete picture of the visual signaling cascade. The visual genes expressed in adult *P. thomassini* provide a template to which we can compare future transcriptomes of larval opsin expression. Continuing studies will incorporate transcriptomes from additional larval stages to create a clearer picture of developmental transitions in stomatopod vision.

P3.109 PALMATARY, H*; AKANYETI, O; LIAO, JC; Washington and Lee University, University of Florida; *otar@whitney.ufl.edu*
Investigating Collective Spatiotemporal Learning in Adult Zebrafish
Pavlovian conditioning, whereby an animal is trained to respond to a specific stimulus, is a powerful assay to study learning and memory. However, the majority of studies have focused on learning in isolated individuals. Moreover, these studies typically evaluate learning performance in binary groupings of successful or unsuccessful conditioned responses. In nature, many organisms occupy social groups and experience learning as a complex dynamic process that changes over time. Here, we designed a classical conditioning experiment to study the temporal progression of collective learning in adult zebrafish (*Danio rerio*, n=24 fish). Pairing a hydrodynamic stimulus (30 Hz vibrating dipole lasting 20 seconds) with food pellets (introduced 10 seconds after the stimulus onset), we trained fish to swim to a specific location to be fed. Experiments were conducted in a 10-gallon tank over a four week training period with three trials per day. For each trial we continuously filmed the activity for 5 minutes before and after the stimulus onset and recorded the number of fish in the feeding location every second. We found that the group size that successfully anticipated food after the stimulus onset increased gradually through the end of week three and then plateaued (n=22, Weibull function, $R^2 = 0.92$). Interestingly, during the fourth week fish continued to learn, this time improving the precision of task execution by delaying their arrival to the food location after stimulus onset, and by departing from the food location more quickly after feeding. This demonstrates that zebrafish can learn the time interval between dipole onset and food introduction as well as the frequency of food introduction per trial. Our results suggest that collective learning during classical conditioning progresses in waves where animals are capable of forming complex level associations between stimuli over time.

P2.269 PALMER, R*; BUCKLEY, B; Portland State Univeristy, Portland State University; *rmp@pdx.edu*
The interactive effect of salinity and temperature in the Nile Tilapia
Global climate change is altering the environment of aquatic species in a variety of ways that strongly influence the physiology of these species. Physiological studies are crucial to predicting how species will respond. Most physiological studies focus solely on one stressor. However, to best understand how an organism will respond to external perturbation, multiple stressors and their interactions must be studied. In order to discover the interactive effect of salinity and cold temperature Nile tilapia will be subjected to a variety of stress treatments. Nile tilapia (*Oreochromis niloticus*) provide an ideal model to study the combined effect of temperature and salinity as it inhabits freshwater systems that are vulnerable to sea level rise, and because of the large amount of genetic information available for this species. The biogeography of tilapia may change as sea level rises rendering their current niche uninhabitable. To predict whether tilapia and other freshwater species will exhibit a shift in distribution, we need to better understand how the severity of salinity and temperature stress, separately and in combination, will affect such species. Nile tilapia (Oreochromis niloticus) were subjected to a 1 hr stress treatment where salinity and temperature were manipulated. Treatments were either 22°c or 14°c, and varied salinities of 0ppt, 16ppt, or 34ppt. All fish survived the treatments. Tissues were then collected, and assayed using flow cytometry and ELISA's for PCNA and p53.

P1.192 PALMER, RM*; STAAB, KL; McDaniel College; *rmp005@mcdaniel.edu*
Not all cypriniform jaw ligaments are equal: the functional morphology of kinethmoid ligaments and their role in premaxillary protrusion
Cypriniform fishes possess a median sesamoid bone in their upper jaw, termed the kinethmoid; it is a synapomorphy for the order and facilitates premaxillary protrusion. The kinethmoid is attached via ligaments to bones in and around the upper jaw: the maxillae, premaxillae, palatines and neurocranium. The jaw muscles, specifically the A1 division of the adductor mandibulae, insert on the maxillae and initiate forces that are transmitted to these kinethmoid ligaments. This rotates the kinethmoid, pushing the premaxillae into a protruded state. Little has been done to identify the composition or function of these kinethmoid-associated ligaments. Furthermore, teleosts possess a wide range of cartilage-like connective tissues (CLCTs), but little is known about their function and most work has been qualitative. Using histology, the morphology of each kinethmoid ligament was studied and various stains were applied to determine the components of the extracellular matrix. ImageJ was used to determine the ratios of cells to extracellular matrix (ECM) as well as absolute cell size in an effort to begin to standardize the identification methods in various teleost CLCTs. The premaxillary ligament, which undergoes compressive forces during feeding, is composed of hyaline cell cartilage (HCC). HCC is a highly cellular tissue with little ECM, permitting the kinethmoid to push the premaxillae into a protruded state. Gaining knowledge of the composition and function of the CLCTs in teleosts can give us not only a better understanding of fish feeding and premaxillary protrusion, but this information can be applied to other anatomical and morphological structures in teleosts, aiding in the a more complete understanding of teleost anatomy.

69.3 PALMQUIST, KH*; DAVIDSON, BJ; Swarthmore College; *kpalmqu1@swarthmore.edu*
Ion flux controls left-right heart and gut asymmetry in Ciona intestinalis.
During development, bilaterian organisms are patterned along the left-right axis. While the TGFβ-family member, Nodal, is thought to play a highly conserved role in this process, the impact of other signaling mechanisms on this process is poorly characterized. To better understand what other signaling pathways contribute to asymmetric organogenesis, we employ the tunicate *Ciona intestinalis*. We have found that the *Ciona* heart and gut-tube are positioned on the right side of developing juveniles. Asymmetric positioning of these organs is first observed during larval stages. Intriguingly, we show that while nodal signaling is crucial for proper gut asymmetry, it is dispensable for heart asymmetry in larva. Through inhibitor experiments, we have found that H^+/K^+-ATPase dependent ion flux is necessary for proper heart and gut positioning in both larvae and juveniles. Based on our findings, we hypothesize a model where ion flux and ciliary flow act through a feed-forward mechanism to direct heart and gut asymmetries. These results provide the groundwork for future studies pinpointing the mechanisms underlying left-right patterning in vertebrates.

135.6 PAN, T-CF*; APPLEBAUM, SL; MANAHAN, DT; Univ. of Southern California, Los Angeles; *tienchip@usc.edu*
Biochemical Bases for Growth Phenotype Variation in Marine Larvae of Different Genotypes
Mechanistic understandings of the causes of size variation and the ability to predict growth potential of marine invertebrates remain challenging. In this study pedigreed lines of the Pacific oyster (*Crassostrea gigas*) were crossbred to produce larval families of different genotypes that were reared under similar environmental conditions. Across different larval families, there was a ~4-fold range in daily growth rates, with protein being the major biochemical component that increased during growth. There were family-specific variations in rates of protein synthesis and protein depositional efficiency during growth. While faster-growing larvae would have an advantage of completing the larval phase in a shorter time, our analyses of metabolic allocation revealed an important tradeoff between fast growth and increased energy allocation to protein synthesis. Tradeoffs between growth phenotype and energy use could be a determinant of survival for larvae of different genotypes responding to the stress of environmental change.

P2.143 PANYI, AJ*; LILLIS, A; MOONEY, TA; Univ. of Southern Mississippi, Ocean Springs, Woods Hole Oceanographic Institution, MA; *apryle.panyi@usm.edu*
Light effects on individual behavior and sound production by snapping shrimp, Alpheus heterochaelis
Snapping shrimp are a cosmopolitan group of marine crustaceans consisting of hundreds of tropical and temperate species, many of which are recognizable by a large, specialized claw. Snap production results from rapid claw closure, during which a cavitation bubble pops. The short-duration snap is one of the loudest bioacoustic sounds in the marine environment, and their colonies create a pervasive and continuous crackling in many coastal habitats. Despite the contribution of snapping to marine soundscapes, relatively few studies have investigated related acoustic patterns or the underlying behavioral ecology. Recent field recordings have shown tremendous spatiotemporal complexity in snapping shrimp sound production, including variable diurnal rhythms, but the environmental drivers are unclear. In this study, the effect of light on snapping shrimp behavior and snap production was investigated for *Alpheus heterochaelis*. Snap rates were compared for individual shrimp in isolated chambers under different light treatments (constant light, constant dark, ambient day-night cycle). Shrimp showed high individual variability in snap rate but overall higher snap rates in complete darkness. In further experiments to observe behavior under different light conditions, 2-h video recordings of individuals in isolated chambers in a light or dark treatment were made. Shrimp behaviors were categorized: exploration, excavation, fixed position (cleaning, feeding), and snapping. Results showed that exploration and excavation behaviors differed between the light and dark treatments but fixed position and snap behaviors did not.

P2.180 PARKER, MR*; RICHARD, SA; FLORES, RJA; AVERY, ML; James Madison Univ., US Dept. of Agriculture - APHIS; *mrockwellparker@gmail.com*
Conspecific scent trailing and initial identification of social chemical cues in Burmese pythons
Invasive predators pose significant problems at the ecosystem level, but solutions that target reproductive interactions in invasive animals have been successful in multiple species. The Burmese python (*Python bivittatus*) is an invasive species of concern in the Florida Everglades that threatens native vertebrates, especially birds and mammals. The reproductive biology of this species of python is poorly understood in its invasive range in the Everglades, and the primary goal of our research is to establish fundamental knowledge of their chemical communication at multiple levels of inquiry. Sex pheromones in many (if not all) species of snakes reside in the skin's lipid matrix and can be extracted from whole animals and their shed skins. We isolated lipids from Burmese python sheds (n=9 females, n=7 males) for use in bioassays and analytical chemical analyses. In chemical analyses, we observed sexually dimorphic variation in cholesterol metabolites in the extracts and have detected intrasexual and seasonal variation. In bioassays with male pythons (n=7) trailing lipid extracts in a Y-maze, males demonstrated increased chemosensory investigation toward female, but not male, scent based on tongue-flicking rates. Males also showed an array of behaviors in the Y-maze outside the predicted breeding season in their invasive range, and two of these behaviors were more frequent in the presence of female scent. If chemical cues are used by male Burmese pythons to locate mates, these cues could be implemented in field strategies to control the reproduction and spread of this invasive predator.

P1.289 PARKER, AK*; MCHORSE, BK; PIERCE, SE; Harvard University; *abigailparker@college.harvard.edu*
Habitat Partitioning in Monodactyl and Tridactyl Fossil Horses of North America
Horses (family Equidae) are unique among mammals in being monodactyl, having a single toe. Classically, the evolution of this trait, along with increased body size and tooth height, has been explained as an adaptation to the spread of grasslands. To test the hypothesis that monodactyly arose in grassland environments while tridactyl horses lived in more wooded areas, we used EcoSim to analyze the niche overlap of fossil horse species between different paleoenvironments in the deposits in which they were found. To enable this analysis, we have compiled a dataset of nearly 4000 published occurrences of horse fossils, trait data for each species, and habitat type (forest, savanna, grassland, etc.) of the deposits where fossils were found. This information allows us to place trait evolution in its environmental context, as well as to look for correlation between toe number, body size, and hypsodonty index in incipient grassland species. Our results show low niche overlap in a matrix of all occurrences in habitat categories against number of toes, suggesting that habitat partitioning did occur. Further analysis will subdivide by North American Land Mammal Ages when monodactyl and tridactyl horses coexisted, which may continue to support this hypothesis or, if monodactyl and tridactyl horses are not found in significantly different environments, call into question the interpretation of monodactyly arising due to an adaptive advantage in grasslands. Our analysis integrates occurrences, fossil traits, and past vegetation patterns in North America and will shed light on an important relationship between adaptive trends in horse evolution and environmental changes.

P2.184 PARRISH, SC*; MCCOY, MW; East Carolina University; *parrishs15@students.ecu.edu*
The Effects of Pharmaceuticals and Personal Care Products (PPCPs) and a Predator on Mosquito Oviposition Site Selection and Adult Recruitment
Constructed wetlands are a common, cost-effective method for filtering municipal wastewater which typically contains low concentrations of pharmaceuticals and personal care products (PPCPs). These wetlands provide an ideal breeding habitat for a diverse array of organisms including disease vectors and nuisance species such as mosquitoes. Mosquito predators, such as mosquito fish, are often used as a biological means of reducing mosquito populations by either directly consuming the mosquitoes or by deterring female oviposition in aquatic habitats. However, it is unclear how PPCPs affect the ecology of wastewater wetlands. In this study, we examine how three common PPCPs, in conjunction with predator kairomones, affect oviposition site choice and larval performance of mosquitoes. We quantify differences in oviposition, hatching success, larval abundance, and adult emergence in experimental mesocosms with and without predator kairomones and with or without the presence of either an antimicrobial disinfectant (Triclosan), a stimulant (Caffeine), an insect repellent (DEET), or a mixture of all three chemicals. Our results can have important implications for the management of mosquitoes and for understanding how PPCPs, that are ubiquitous in both constructed and natural waterways, may be affecting the ecology of these systems.

P1.257 PARSONS, ZM*; RACHOCKI, L; OYEN, KJ; JARDINE, LE; LOZIER, JD; DILLON, ME; University of Wyoming, University of Alabama; *zparsons@uwyo.edu*
Geographic Variation in Bumblebee Flight Morphology Suggests Aerodynamic Limitations on Upslope Range Shifts
Geographic ranges of diverse species have shifted poleward and up mountain slopes in response to warming climate. Upslope range shifts facilitate tracking of climatic niches over very short geographic distances. However, flying organisms moving upslope encounter a novel challenge -reduced air density should limit force production necessary for flight. Whether flying insects may overcome this aerodynamic limitation to upslope range shifts through changes in flight morphology is largely unknown. Recent studies have revealed climate-driven northward and upslope range shifts for dozens of European and North American bumblebee (genus *Bombus*) species, which thrive in diverse habitats from sea level to over 5000 m elevation. We measured geographic variation in flight morphology of two Western North American bumblebees (*Bombus vosnesenskii* and *Bombus bifarius*) collected across multiple years and seasons from 36 to 48 °N latitude and from sea level to over 2900 m in elevation. We measured body mass of field-caught foragers before and after emptying the crop, and wing area by analyzing images of clipped wings of over 1500 individual bees. The alpine specialist, *B. bifarius* was smaller overall, with field mass increasing significantly with latitude and altitude. The larger species, *B. vosnesenskii*, showed no change in body size with latitude or altitude. Wing loading (body mass relative to wing area) changed little with latitude but decreased strongly with altitude, particularly for *B. bifarius*. Relatively high wing loading and limited changes in wing loading with altitude for *B. vosnesnskii* may limit the ability of this species to move upslope to track climate change.

P2.44 PASCAR, JA*; CHANDLER, CH; State University of New York at Oswego; *jpascar@oswego.edu*
Testing for the Prevalence of Wolbachia in Two Terrestrial Isopod Species (Porcellio laevis and Trachelipus rathkei)
As more studies regarding host-microbe interaction are being published the trend shows just how much of an impact microbes can have on a host. Whether a microbe acts commensally, mutualistically, or pathogenically the impact that they have on the host species can exhibit a variety of effects. Specifically, one way that microbes can affect a host is through altering their sex-determination mechanism. Among arthropods one of the most widespread bacterial infections is *Wolbachia*. *Wolbachia* is transmitted vertically, directly from mother to offspring through the eggs, and is known to cause four different types of reproductive changes to its host species: feminization, cytoplasmic incompatibility, parthenogenesis, and male-killing. In terrestrial isopods, feminization by *Wolbachia* is thought to skew sex ratios in favor females, but cytoplasmic incompatibility has also been observed. Both *Porcellio laevis* and *Trachelipus rathkei* follow the ZZ/ZW sex-chromosome determination system. Ultimately, feminization theoretically could lead to the loss of the W chromosome. To begin to understand the effects of *Wolbachia* infection in these two isopod species, we tested for the presence of *Wolbachia* using PCR. We are in the process of setting up crosses to further examine the effects of *Wolbachia* in these hosts.

P1.195 PASCUAL, S*; WORTHAM, J/L; University of Tampa; *stephanie.pascual@spartans.ut.edu*

A comparison of form and function: grooming appendage setal morphology and grooming behaviors of the blue crab (Callinectes sapidus) and stone crab (Menippe mercenary) (Crustacea: Decapoda: Brachyura).

Grooming behaviors have been documented in many crustaceans, with a focus mostly on shrimps. Setal morphologies of the associated grooming appendages of these studied species are elaborate, as well as variable, depending on the body regions groomed, fouling intensity, and overall time budget for grooming. In brachyurans, little is known about the grooming behaviors and related setae; besides spider crabs, there is not any detailed information about this commercially important group. Little is known about the grooming behaviors or fouling of the economically important blue crab or stone crab. Because blue crabs are more active and likely exposed to more fouling than stone crabs, blue crabs were predicted to have higher grooming pressures, resulting in higher grooming activities. In this research, grooming behaviors of these two crab species were observed, each for over 40 hours. Body regions groomed and by which body appendages was recorded as well as grooming durations. Then, scanning electron microscopy was used to document the setal morphology of the grooming appendages. Results show that stone crabs have a much higher time budge for grooming compared to blue crabs and other decapods. Both species focus grooming on respiratory and sensory structures. Setal morphologies of both species were elaborate, with some setal types reoccurring on the same appendage of both species. Overall, stone crabs have very detailed behaviors and morphologies that seem to keep their fouling levels low in the field.

16.6 PATEK, S.N.*; AZIZI, M.; BHAMLA, M.S.; COX, S.; ILTON, M.; KIM, Y.; KOH, J.; KUO, J.; MA, X.; PRAKASH, M.; SUTTON, G.P.; TEMEL, Z.; Duke U., U. CA Irvine, Stanford U., Penn State U., UMass Amherst, Harvard U., U. MD College Park, Stanford U., U. Bristol; *snp2@duke.edu*

Extreme power amplification in biological systems

The extraordinary accelerations of jellyfish stingers, trap-jaw ant mandibles and mantis shrimp hammers occupy a notable region of extreme mechanical power amplification that yields intense and transient forces directed to the external environment. Systems capable of extreme power amplification share three core components - motors, springs and latches. We have used simple mathematical simulations and a broad comparative dataset to explore the shared features and constraints of these systems. We found that springs are most beneficial when the take-off velocity of a projectile is limited by motor velocity and are not particularly effective when take-off velocity is limited by projectile inertia. Springs are typically tested at low rates and without realistic loading; however, in extreme power-amplified systems, springs actuate the movement and do so at extremely high rates. We found that the loading and rate dependence of hypothetical elastic mechanisms influence power output and velocity. Latches enable power-amplified systems to enhance potential energy storage while separating and controlling the transition from potential to kinetic energy. We found that the mechanical behavior and associated morphology of latches mediate the spring's actuation and the kinematic output of the system. Extreme power amplification offers a window into the costs and consequences of the temporal and spatial separation of motors, springs and latches, while informing how their integration has yielded a remarkable biological diversity of extreme kinematic performance.

143.7 PATEL, KV*; BOHONAK, AJ; SIMOVICH, M; GODDARD, N; BLACK, C; GRAIGE, N; San Diego State University, University of San Diego, San Diego State Univeristy; *Kpatel102486@gmail.com*

Genetic Admixture in the San Diego Fairy Shrimp (Branchinecta sandiegonensis)

Because only 3-7% of historically present vernal pool habitat remains in coastal San Diego County, conservation efforts must prioritize both maintenance of these pools and the genetic integrity of their inhabitants. Simovich et al (2013) suggested admixture between the endemic San Diego fairy shrimp (Branchinecta sandiegonensis) and the versatile fairy shrimp (Branchinecta lindahli). They published a hybrid index based on female dorsolateral spinal patterns (which cannot be used for males and immature individuals). Using morphologically scored females from multiple source populations, we have developed a genomic hybrid index comprised of 23 single nucleotide polymorphisms that are alternatively fixed between the two Branchinecta species. This genomic hybrid index can be used to validate the existing morphological hybrid index, detect hybrid individuals, identify admixture in juveniles and males, and estimate natural admixture rates. Genetic assessment of San Diego Fairy Shrimp populations and genetic monitoring over time will better inform management and conservation practices in the remaining coastal vernal pool ecosystems.

P2.170 PATEL, RN*; CRONIN, TW; University of Maryland Baltimore County; *rickp1@umbc.edu*

Navigating the Benthic Reef: Orientation in Stomatopod Crustaceans

Stomatopods are predatory marine crustaceans renowned for their ballistic strikes and complex visual systems. These animals commonly inhabit holes and crevices in the benthic substrates of marine environments for use as burrows, where they may reside safely concealed from their predators. However, stomatopods forage at extended distances from these burrows before returning back to their homes. This raises the question, how do stomatopods navigate back to their burrows efficiently to limit the risk of predation? Many other central place foragers from a wide taxonomic breadth update their position relative to their point of departure in order to produce a self-generated home vector with which to find the point of departure with the greatest economy. This process, termed path integration, is likely to be used by stomatopods as well. Also, piloting, the process by which an animal follows a landmark or chain of landmarks to a goal, is a likely strategy these benthic organisms use in their structurally complex reef environments. To experimentally determine if these mechanisms are employed, *Neogonodactylus bredini* were placed in featureless circular arenas in a glass roofed greenhouse, with their burrows submerged from view. Foraging paths in the presence and absence of a landmark adjacent to the burrow were recorded. Initial data suggests that return trips in the presence of the landmark are more direct than trips in the landmark's absence. However, the initial direction of the return trips were generally oriented towards the burrow regardless of the presence or absence of the landmark. These results indicate that *N. bredini* may use an integrated compass to determine the direction of its home vector as well as pilot towards landmarks to find its burrow. Additional data must be collected to determine the significance of these results.

P1.214 PATEL, RG*; KENNEDY, EBL; UYENO, TA; CLARK, AJ; College of Charleston, Valdosta State University ; *patelrg@g.cofc.edu*

Comparative Biomechanics of Hagfish Skins

The spectacular knot tying behaviors of hagfishes are a product of their complex axial muscles, loose-fitting skin, and flexible bodies devoid of vertebrae. Slack skins are peculiar body coverings in fishes and other aquatic animals that possess taut skins that are mechanically important in retaining body shape while being flexible enough to permit the body deformations necessary for movement. Like other fish skins, hagfish skins are multilayered biological composites. However, the skins of Pacific hagfish *Eptatretus stoutii* are more compliant circumferentially, while other fish skins are more compliant longitudinally. Body knotting and loose-fitting skins are featured across many species of hagfish, including the well-studied Atlantic and Pacific hagfish, each representative of the two major subfamilies of the Myxinidae: the Myxininae and Eptatretinae. The resting positions, or "postures," of these demersal fishes can be coiled (e.g. Pacific hagfish) or stretched (e.g. Atlantic hagfish). This difference in posture could pertain to differences in the material properties of key anatomical structures like the notochord and the skin. We present the morphology and material properties of the skins from two Myxinines: the Atlantic hagfish *Myxine glutinosa* and *Myxine hubbsi* and compared them with data gathered from *E. stoutii*. Skin samples oriented in longitudinal and circumferential body axes, were subjected to quasi-static uniaxial tensile tests to failure. Skins from both Myxinines are isotropic but comparable in thickness, stiffness, strength, extensibility, and toughness to anisotropic *E. stoutii* skins. The biomechanical variation in these skins appears to be related to the variation in resting postures and knotting kinematics across species.

53.3 PATEL, A*; FISHER, C; STOCKS, B; NICOLLS, F; BOJE, E; University of Cape Town; *a.patel@uct.ac.za*

Tracking the Cheetah Tail and Spine using Animal-borne Cameras and a Wireless Sensor Network

The cheetah (Acinonyx Jubatus) is not only the fastest animal on earth but also the most maneuverable. Naturally, an investigation into the whole-body motion dynamics of this specialized predator will illuminate the various factors which influence and affect performance in legged animals as well as provide insight for the design of future bio-inspired robots. Presently, animal sensor collars can successfully capture the gross animal behavior, but do not provide information about the animal's whole body motion. Here, we demonstrate the use of animal mounted cameras, as well as a wireless Inertial Measurement Unit (IMU) network which are attached to captive cheetahs during maneuvers. The various sensors are fused by a Kalman Smoothing Filter to provide high-bandwidth state estimates of the position and velocity of the cheetah tail and spine. We believe this novel motion capture system will enable high fidelity state estimates on wild animals for future studies.

P2.197 PAYNE, CY*; CARVAJAL, JI; GRUPE, B; ROUSE, GW; Scripps Institution of Oceanography, UC San Diego; *cypayne@ucsd.edu*

A New Species of Sea Daisy (Xyloplax, Asteroidea, Echinodermata)

Xyloplax is a genus of sea stars found on sunken wood in the deep ocean. Their circular and petaloid bodies, which lends them their common name, "sea daisy", and their exclusive diet of wood makes them an unusual and rare element of deep sea ecosystems. There are currently only three described species of *Xyloplax*. A fourth species was recently collected at a depth of 2200 meters near the Juan de Fuca hydrothermal vent system, off Oregon. The specimens were obtained from wood blocks deployed for three years. Though geographically close to another described species of *Xyloplax* from the northeastern Pacific, *X. janetae*, the new species was found to be markedly different, with a corrected mitochondrial COI distance of 17.35%. Scanning and transmission electron microscopy were used to describe the skeletal structure and reproductive organs of the new species.

P3.23 PECK, MR*; WILCOXEN, TE; Millikin University, Millikin University ; *mrpeck@millikin.edu*

The effect of water acidification on the growth, development, and immune defense of Cuban tree frogs, Osteopilus septentrionalis, and American bullfrogs, Rana catesbeianus, in the presence of a pathogen

Freshwater acidification, an issue that is largely linked to industrialization and human activity, poses a threat to natural environments. Amphibians are especially threatened by this issue, due to their permeable skin and sensitivity to environmental disturbances. We exposed Cuban tree frog (*Osteopilus septentrionalis*) and American bullfrog (*Rana catesbeianus*) tadpoles to neutral and acidified water, both with and without the common water bacteria and amphibian pathogen, *Aeromonas hydrophila*. We monitored development, growth and immune defense among tadpoles from different treatments. We found that neither acidity nor the presence of a pathogen, nor a combination of the two, had a significant effect on growth or immune defense, as measured by snout-to-vent length and *A. hydrophila* killing ability, respectively, when considering varying Gosner developmental stages in *O. septentrionalis*. However, *A. hydrophila* killing ability in *R. catesbeianus* was significantly lower in tadpoles exposed to one or more stressors compared to control tadpoles. Our results support the hypothesis that Cuban tree frogs, an invasive species, are resilient to freshwater acidification and pathogen exposure. American bullfrogs, a species native to North America, were negatively affected by the stressors. The results of these experiments could hold implications for the future of native species as a result of increased invasive species survival in the presence of environmental stressors.

85.2 PEIMAN, KS*; BIRNIE-GAUVIN, K; LARSEN, M; COLBORNE, S; AARESTRUP, K; COOKE, SJ; Carleton University, Canada, Technical University of Denmark, University of Windsor, Canada, Technical University of Denmark; *kathryn.peiman@carleton.ca*

Effects of Cortisol on Short and Long Term Diet and Morphology

Glucocorticoids such as cortisol are released during stressful events. However, many of the effects of cortisol on animals in the wild are still poorly documented. We evaluated the effects of artificially elevated cortisol on diet and morphology over the short term (2 weeks) and long term (4 months) using a wild population of juvenile semi-anadromous brown trout (Salmo trutta) in Denmark. We caught, tagged and manipulated juvenile fish while in their natal freshwater streams in the fall. Manipulations consisted of an exogenous intracoelomic injection of cortisol suspended in vegetable shortening (designed to mimic an extreme physiological challenge), a sham group (injection of vegetable shortening) and a control group (tagged only). We then recaptured fish 2 weeks later and again after 4 months. We assessed diet using stable isotopes from plasma (short term) and scales (long term), and morphology using geometric morphometrics. Cortisol affected carbon stable isotope signatures but had minimal effects on nitrogen isotopes and morphology. Irrespective of treatment, carbon and nitrogen stable isotope values increased over time. This study shows that cortisol can have both short and long term effects on individuals in the wild.

P2.227 PEIMAN, KS*; ROBINSON, BW; Carleton University, Canada, University of Guelph, Canada; *kathryn.peiman@carleton.ca*

Trait Covariation Viewed Through a Performance Paradigm Lens

Phenotypic covariation occurs within and among morphological, behavioral, physiological and life history traits at four biological scales: within individuals, within populations, among populations, and among species. However, the causes of trait covariation often change over these scales, making it difficult to use patterns at one scale to infer process at other scales. The proliferation of trait covariation studies has resulted in increasingly specialized terminology that is used to describe many patterns of phenotypic correlation, often independent of the scale of covariation and of any explicit structural, functional, or evolutionary hypotheses about why and how traits are related. We use a functional performance framework to identify different trait relationships and then we link these to fitness landscapes in order to explore hypotheses about the form and evolution of trait relationships. Our approach generates predictions about how covariance structure should change within and among populations under different forms of selection. This framework is not trait- or taxon-specific and is relevant to studies from individuals to species. It also contributes to our understanding of phenotypic evolution by allowing us to better classify the performance consequences of trait linkage and use these to develop hypotheses about genetic architecture, evaluate the interplay between selection and constraint, and explain the persistence of maladaptive traits.

136.6 PELEG, O*; PETERS, J; SALCEDO, M/K; MAHADEVAN , L; Harvard University; *opeleg@seas.harvard.edu*

Dynamic Morphology in Honeybee Swarms

Honeybee colonies often form swarms [1] wherein the queen and workers bees (on average ~10,000 bees) may gather in a tree or on a branch and send scout bees out to find new suitable nest locations. Generally, the swarm takes on an inverted cone shape where the bees hold on to each other, and form a large structure that can be hundreds of times the size of an organism. The aspect ratio of the cone depends on the geometry of the branch (or other attachment surface). The mechanisms by which a multitude of bees work together without an overseer to create a stable structure that compete with gravity remains elusive. Here we combine both experimental observations and modeling, to test the role of mechanical cues in honeybee swarm morphogenesis. In the experiments, mechanical perturbations were applied to a swarm. In response, the bees tune the aspect ratio of the cone dynamically. As the frequency of perturbation increase, the larger the base of the cone and the shorter its height become. Furthermore, we explored the formation of the swarm and its response to mechanical perturbations using an agent based simulations and confirmed a mechanism by which individual bees are capable to sense mechanical stresses, and respond by changing the global shape of the swarm. Together these observations suggest a new paradigm for sensing and feedback-driven stabilization of structures made of active elements. [1] T. D. Seeley, Honeybee Democracy, Princeton University Press, 2010

P3.168 PELLETIER, G*; FREDERICH, M; Univ. of New England, Biddeford; *gpelletier@une.edu*

Differential Stress Tolerance at Varying Stages of the Molt Cycle in the Juvenile European Green Crab, Carcinus maenas

The European green crab, Carcinus maenas, is variable in ventral sternite coloration, green after molting and often dark red after prolonged intermolt. Previous studies reported that red morphs are less stress tolerant than green morphs. In this study we test for stress tolerance changes throughout the molt cycle. Juvenile animals were collected 4-7 days after molting and assessed for various stress markers through the course of a full molt cycle. Animals were greenest 1-2 weeks after molting, before slowly turning yellow. No animals reached the dark orange and red stages typical of a prolonged intermolt, with the intermolt lasting from 40 to 83 days. Molting caused a carapace width increase of 14.7% to 33.7%. Animals were assessed for stress tolerance by righting response in normoxic conditions, and after 45 minutes of hypoxia exposure. Righting response remained constant through the molt cycle in both normoxic (1.5±0.2s), and hypoxic conditions (5.7±0.4s). Hemolymph lactate concentrations rose steadily through the molt cycle from 0.25±0.15mM directly after the first molt, to 2.83±0.34mM directly before the second molt, and dropped off sharply after the second molt (1.03±0.51mM). Oxygen consumption decreased from 0.17±0.06 µmol O_2 $min^{-1}g^{-1}$ in the first week to 0.11±0.03 µmol O_2 $min^{-1}g^{-1}$ in the tenth week. Overall we observed a gradual decrease in hypoxia tolerance during the molt cycle, which might be associated with an increasingly thicker cuticle on the gills, leading to decreased O_2 uptake and a subsequently decreased scope for aerobic activity. This gradual transition towards reduced stress tolerance through the molt cycle can affect the overall tolerance of a population of green crabs during severe environmental events.

P3.88 PENDERGAST, A.M.*; ZANI, P.A.; Univ. Wisconsin-Stevens Point; *pzani@uwsp.edu*

The influence of temperature on the overwintering behavior of side-blotched lizards in nature

Throughout the winter, reptiles utilize hibernacula (overwintering sites) to avoid harsh conditions. Previous research has shown that emergence may be common throughout the winter and due to cues such as temperature, barometric pressure, or solar irradiance. This study focuses on the emergence behavior of side-blotched lizards in nature with our goals to clarify how temperature influences i) daily emergence, ii) seasonal patterns of emergence, and iii) microhabitat preference in naturally occurring vs. artificial hibernacula. To test these ideas we utilized naturally occurring hibernacula (rock crevices) as well as an artificial overwintering site in the wild. Temperature and, to a lesser extent, barometric pressure can explain lizard emergence throughout the winter in natural hibernacula. Temperature is also the primary factor responsible for an observed seasonal pattern of emergence as winter progresses. Moreover, there are microhabitat differences in daily timing of emergence, suggesting that microhabitat use is related to temperature. Overall temperature appears to be the primary factor governing a multitude of behavioral patterns in seasonal ectotherms.

P1.196 PENNING, DA*; MOON, BR; Missouri Southern State University, Joplin MO; University of Louisiana at Lafayette, Lafayette LA, University of Louisiana at Lafayette, Lafayette LA; *penning-d@mssu.edu*

Identifying the Mechanisms of Predation: In Vivo Measurements of Force and Endurance in Epaxial Muscles of Kingsnakes (Lampropeltis holbrooki) and one of Their Prey Snakes (Pantherophis obsoletus).

Many snakes use their musculature to constrict and kill prey by exerting forces that the prey experience as pressures. Previous work has shown that snake-eating snakes (kingsnakes; *Lampropeltis*) produce higher constriction pressures than similarly sized intraguild competitors (ratsnakes; *Pantherophis*). Although kingsnakes produce higher constriction pressures than their ratsnake prey, there are currently no identifiable differences in their muscle anatomy. Because of their similar anatomy, previous work has suggested that differences in performance may be driven more by posture than by muscle performance. However, quantitative analysis of muscle performance is still needed. We investigated muscle physiology by quantifying *in vivo* muscle force and endurance in two epaxial muscles of kingsnakes (*L. holbrooki*;N = 8) and ratsnakes (*P. obsoletus*;N=8) to test for potentially superior muscle performance in kingsnakes. The semispinalis-spinalis and longissimus dorsi muscles from larger snakes produced higher forces (0.23-1.35 N), but there was no significant difference in max force between muscles or species. In endurance tests, all muscles lost 25% of their max force in an average of 58 s, and muscle force was reduced to an average of 38% of the max over a 4 min stimulation. There was no significant relationship between body size and endurance, and there was no difference in endurance between muscles or species. These and previous results indicate that kingsnakes are superior constrictors that can prey upon other large constrictors not because they have superior muscle performance, but because they use a more consistent and effective coil posture.

P1.139 PEPPER, AW*; WILSTERMAN, K; BENTLEY, GE; UC Berkeley; *aimee.pepper@berkeley.edu*

Thinking outside of the axis: The mammalian ovary can respond to physiological cues without neural input

The hypothalamus is a primary site for the integration of information that regulates reproductive function. In response to cues of psychological and metabolic stress, the hypothalamus decreases production and release of gonadotropins to decrease ovarian stimulation. However, the ovary itself expresses receptors to many of the same hormonal and chemical signals as the hypothalamus, and may modulate steroid production directly in response to such cues. We used *in vitro* culture experiments, hormone analysis, and quantification of gene expression to develop a comprehensive understanding of how mouse ovaries, even in the presence of gonadotropin stimulation, respond to specific physiological cues of stress. After 6 hrs of exposure to 400 ng/ml corticosterone (CORT), ovaries decreased progesterone production (P=0.03; n=6). In contrast, after exposure to 5 mM 2-Deoxy-D-Glucose (2-DG), a pharmacological agent that mimics hypoglycemia, ovaries increased progesterone production (P=0.04; n=5). There was no change in steroidogenic enzyme expression in ovaries exposed to CORT, while there was an increase in StAR (P=0.01) and P450scc (P=0.02) expression in ovaries exposed to 2-DG. Elevated production of progesterone in response to 2-DG treatment is consistent with the role for progesterone in glucose regulation. However, the mechanism by which glucose regulates progesterone production is unknown. Elevated progesterone production by ovaries exposed to 2-DG concomitant with an increase in StAR and P450scc expression demonstrates that ovarian steroidogenesis pathways can respond directly to metabolic cues, even when gonadotropin stimulation is high. Ultimately, these findings demonstrate that the ovary has the capacity to integrate metabolic cues alongside gonadotropin cues from the brain and pituitary.

P2.38 PERELMUTER, JT*; SISNEROS, JA; FORLANO, PM; CUNY Graduate Center, U of Washington, CUNY Brooklyn College; *jperelmuter@gradcenter.cuny.edu*

Dopaminergic Modulation of Hearing in the Plainfin Midshipman Fish

Although dopamine has been identified as an efferent neuromodulator in the rodent peripheral auditory system, its functional role in audition related to adaptive behaviors is unknown, and similar investigations have not been conducted in anamniotes. Our lab has identified dopaminergic innervation in the inner ear of the plainfin midshipman (*Porichthys notatus*), a marine teleost that utilizes vocal signals for seasonal reproduction. Females undergo a hormone-dependent enhancement of hearing during the summer reproductive season that coincides with a reduction in the dopaminergic input to the ear, suggesting that dopamine has an inhibitory effect on inner ear physiology. We therefore tested the hypothesis that dopamine would reduce the auditory sensitivity of the saccule, the main organ of hearing in midshipman. Auditory evoked potentials of saccular hair cells were recorded in the presence of dopamine and receptor agonists. Dopamine and a D2 receptor agonist (quinpirole) inhibited auditory evoked responses by raising thresholds (i.e., decreasing auditory sensitivity), however a D1 receptor agonist (SKF-38393) had no effect. Furthermore, a D2 receptor antagonist (sulpiride) blocked the inhibitory action of dopamine. Our results suggest that seasonal changes in dopaminergic tone may be an important mechanism that contributes to the seasonal plasticity of auditory sensitivity reported for the midshipman. This is the first demonstration of dopaminergic modulation of inner-ear auditory sensitivity in an anamniote and raises the possibility that dopamine may be a conserved modulator of peripheral auditory processing across vertebrates.

P2.116 PEREZ, JH*; WINGFIELD, JC; RAMENOFSKY, M; Univ. of California, Davis; *jhperez@ucdavis.edu*

Endocrine regulation of autumn migration: a role for thyroid hormones?

The annual migrations of animals to their seasonal breeding grounds and back again has long been a topic of interest to researchers. However, studies examining the mechanisms controlling migration have been disproportionately focused on the vernal stage. As a result, we have begun to disentangle the complex system of environmental cues, neuroendocrine and endocrine systems responsible for the transition from the wintering to spring life history stages, yet, we know little about the processes controlling autumn migration. There is strong evidence from vernal studies supporting a major role for thyroid hormone action in the expression of vernal migration. Therefore, we predicted that T4 and T3 might also be involved in autumnal migration. Here we present the results of a chemical inhibition of thyroid hormone production by methimazole in captive white-crowned sparrows during the period prior to and during autumn migration in their free-living counterparts. Expression of the autumn migratory life history stage was assessed via physiological parameters of fat deposition, pectoralis muscle profile, and body mass, as well as recordings of locomotor nocturnal activity levels to determine the presence of migratory restlessness. Contrary to our prediction, we found that methimazole treated birds showed increases in body mass and fat scores; there was no discernible effect on nocturnal activity patterns. These observations stand in contrast to previous studies employing chemical inhibition of thyroid hormone production on vernal migration, which inhibited all aspects of the life history stage measured. Hormonal control of autumnal migration remains obscure, but these data indicate a broader approach to identifying potential mediators is necessary.

P2.142 PEREZ, M*; MELENDEZ, A; OSKAY, D; AGOSTO, J; UPR, NKU; *melina.perez2@hotmail.com*

The Role of a Protein Diet on the Survival and Ontogeny of Circadian Rhythm in Apis mellifera

Circadian rhythms in honeybees are involved in processes that impact colony survival. Young bees take care of the brood constantly throughout the day and lack circadian rhythms, while foragers use the circadian clock to remember and predict food availability in subsequent days. Based on previous work, it is thought that development of circadian rhythms both in field and laboratory began at around 8-9 days of age for young workers. However, not much is understood about the postembryonic development of circadian rhythms in honeybee workers. Recent studies provide evidence that the colony environment may play a role in enabling the circadian rhythms long before onset of foraging. However, the factors in colony environment that regulate development of circadian rhythm is still unknown. Young bees tend to have a protein-rich diet compared to foragers but whether this diet plays a role in the ontogeny of the circadian rhythm remains to be elucidated. We examined the effects of a protein diet on the ontogeny of circadian rhythms of young bees under controlled laboratory conditions. We hypothesized that the protein diet will increase the number of rhythmic individuals and improve rhythmicity. In addition to increase their survivability. We fed one-day-old honeybees with either sugar diet, sugar with 5% protein and sugar-pollen mixture. Results show that there was no significant difference in the quality or the number of individuals in the development of the rhythm. However, the mortality rate of the bees that had the sugar with 5% protein and sugar-pollen mixture improved significantly in comparison with the bees that were fed only sugar. The data presented in the current study shows that the food given to the honey bees do make a difference in the survivability yet does not affect the development of their circadian rhythm.

P1.155 PERKINS, AL; CRABTREE, L; REITZEL, AM*; Purdue Univ., Univ. North Carolina, Charlotte; *areitze2@uncc.edu*

Roles for Exposure Duration and Geographic Origin for Temperature-Induced Heat Shock Protein Expression in an Estuarine Cnidarian

Organisms in estuarine habitats experience dramatic changes in temperature and other abiotic factors over daily and seasonal time scales. For species with broad geographic ranges, the magnitude and duration of thermal stress will vary, which may result in divergent responses between individuals as a result of local adaptation. The starlet sea anemone, *Nematostella vectensis*, inhabits estuaries along the United States' Atlantic coast where individuals experience >20°C changes every day and more than 40°C over a year. The range of temperatures as well as the mean high temperatures vary along this coast due a sharp thermocline from Florida to Maine to which many species show evidence for thermal adaptation. For this research, anemones were collected from throughout their native range and used to examine the effects of temperature changes on cellular stress. A group of inducible heat shock proteins (HSP) are produced in response to stress, such as temperature increases, and can be used as biomarkers. Individuals from three genetically distinct anemone populations in Maine, Massachusetts, and North Carolina were studied to compare the interpopulation differences in inducible HSP production in response to temperature change. Quantitative PCR was used to measure HSP expression in response to acute [two degrees Celsius every hour for eight hours (20 - 36°C)] and chronic temperature treatments. Our results reveal significant differences in expression of these HSPs with respect to the magnitude and duration of temperature increase but little variation between populations. Studying the interpopulation differences in response to temperature change can provide insight on how sea anemone populations will respond to climate change throughout its native range.

48.2 PERLMAN, BM*; LI, CY; ASHLEY-ROSS, MA; EARLEY, RL; Wake Forest University, University of Alabama, Tuscaloosa; *bperlman@alumni.wfu.edu*

Exercise induces sex change in an amphibious fish

Mangrove rivulus (*Kryptolebias marmoratus*) are self-fertilizing hermaphroditic teleost fish that range from Central Florida to Central America and that make occasional forays onto land in search of prey, to escape poor water conditions, or to thermoregulate. In a previous study, we observed that terrestrial behaviors varied considerably among animals originating from different geographical regions. In an attempt to study how regular training would affect jumping performance of individuals from different populations throughout the range, we conducted exercise trials once per week. These trials consisted of a fish being placed into a shallow pool (110 cm diameter) with wetted bench liner and induced to jump via tail-flipping by chasing it for one minute with the end of a blunt dowel. Within a few weeks, some specimens from particular populations in the Florida Keys began to change color from mottled brown to orange, indicative of the fish transitioning sex from hermaphrodite to male. Interestingly, we observed these phenotypic color changes to occur at different temporal intervals and different intensities across different lineages. Environments in which males experience greatest fitness and/or environments that shift the cost:benefit ratio of being one sex or the other, should favor sex change. The proximate mechanisms underlying exercise-induced sexual transitions are unknown but we hypothesize a shift in sex steroid hormone profiles accompanying phenotypic color changes. Understanding the plasticity of gene expression and physiology that initiate sex change will help us understand how the environment affects life history strategies of this self-fertilizing fish.

120.5 PERRON, J; VERDE, EA*; ONTHANK, KL; St. George's University, Grenada, Maine Maritime Academy, Walla Walla University; *alan.verde@mma.edu*

Octopus rubescens' Prey Handling Procedures are Influenced by Bivalve Shell Thickness and Adductor Muscle Strength

Most generalist predators are faced with an assortment of preparation and handling decisions to make prior to consuming their prey. Octopuses commonly preying on mollusk and gastropod species that are protected by a calcified exoskeleton (shell), attempt to pull the shells apart or drill into the shell. This study was conducted to determine which feature of bivalve shells, shell thickness or adductor muscle strength, influenced the red octopus' penetration techniques the most. Red octopuses (*Octopus rubescens*) were fed a single species of clam once a day over the course of 11 days and the handling time of each feeding trial was measured. *Octopus rubescens* presented with thin shelled (*Nuttalia obscurata*) vs. thick shelled (*Venerupis philippinarum*) bivalves, utilized different mechanisms for processing them. Octopuses used their tentacles and suckers to pull apart the thin shelled bivalves, but thick shelled bivalves, with nearly three times the pulling resistance of thin shelled bivalves, were more commonly drilled, presumably to inject paralyzing venom. Consequently, octopuses that drilled bivalve shells took 6.8 times longer to consume their prey than those that physically pulled the shells apart. Regardless of shell thickness, bivalve handling times continually decreased from day 1 to day 11 which suggests that *O. rubescens* uses a sophisticated working memory to learn and adjust their bivalve prey handling behavior. By using the "ideal" method for opening different types of bivalves, *O. rubescens* may be utilizing optimal foraging strategies when manipulating and processing bivalve prey.

9.6 PETERS, JM*; PELEG, O; COMBES, SA; MAHADEVAN, L; Harvard University, Univ. of California, Davis; *jcbptrs@gmail.com*

Honey Bee Colonies Use Flow-mediated Stigmergy to Minimize Shear During Collective Nest Ventilation

Honey bee (*Apis mellifera*) colonies nest in pre-existing cavities that often have a single, small opening to the environment. In order to ventilate their nests, honey bees must exchange air with the environment through this opening. When nest temperatures are high, individual bees position themselves at the nest entrance and fan their wings, actively drawing air out of the nest. At steady state, groups of fanning honey bees are clustered together in small regions of the nest entrance establishing local outflow while passively drawing air into the nest elsewhere along the entrance. The position and number of these fanning groups varies over time. Using a custom flow-sensing device, we monitored the position of fanning groups and their influence on flow patterns at the nest entrance over the course of several weeks in three colonies. Of the infinite number of possible distributions of fanning bees along the entrance, our data suggests that fanning bees assume only distributions that minimize shear between inflow and outflow through the nest entrance. We use both computational and robotic models to demonstrate that honey bees likely use flow-mediated stigmergy to structure airflow at the nest and minimize energy loss to friction. Individuals respond to local temperature cues, but induce flows that have non-local effects on the behavior of the group.

P2.39 PETERSEN, CL*; KLEIN , TLW; KINGSBURY, MA; HURLEY, LM; Indiana University, Bloomington ; *chlpete@indiana.edu*

Regionally Distinct Activity in the Dorsal Raphe During Mouse Courtship: A Potential Link Between the SBN and Auditory Processing?

While affective information influences sensory processing, the anatomical connections between social behavior circuits and sensory regions such as the auditory system are poorly understood. Male mice (*Mus musculus*) interacting with females show a valence-dependent increase of serotonin (5-HT) within in the inferior colliculus (IC), an auditory midbrain structure important for processing vocalizations. However little is known about the anatomical substrates that facilitate 5-HT signaling in the IC. We used multi-fluorescence immunohistochemistry for tryptophan hydroxylase (TPH; the rate limiting enzyme in 5-HT synthesis) and the immediate early gene product Fos to test whether sub-regions of the dorsal raphe nucleus (DRN), the primary source of 5-HT to the IC, are differentially activated during sexual encounters in male mice. Additionally, we tested whether vasopressin (AVP) neurons within the bed nucleus of the stria terminalis (BNST) and paraventricular nucleus of the hypothalamus (PVN), 2 DRN afferents within the brain's social behavior network, showed functional connectivity with DRN subcomponents. Fos immunoreactivity (-ir) within serotonergic (TPH-ir) neurons in the lateral DRN were correlated with male mounting behavior; similarly, this pattern related to female squeaks, a vocal cue associated with mounting. While there was no relationship in activity between AVP-ir neurons and lateral DRN neurons, we did find functional connectivity between BNST and other DRN subcomponents. By comparing these data with Fos-ir in IC we can start to elucidate a functional circuit-level mechanism for 5-HT release into the auditory system.

S5.3 PETERSEN, JM; University of Vienna; *petersen@microbial-ecology.net*

Friends with unexpected benefits: New discoveries on the roles and functions of marine chemosynthetic symbioses

All animals evolved and live today in a countless and immensely diverse 'sea' of microbes. Despite this, hundreds of marine animal species have evolved intimate associations with one or a few specific types of chemosynthetic bacteria, which provide them with nutrition. The chemosynthetic symbionts are at least as diverse as their hosts, and have evolved from numerous bacterial lineages multiple times in convergent evolution. ‘Omics' technologies have helped to usher in a new age of discovery on these so-far uncultivated organisms. Previously, only sulfide and methane were known to power chemosynthetic symbioses, but we recently showed that they can also be fuelled by hydrogen. Carbon fixation by sulfur-oxidizing symbionts is well established, but we have also discovered the genes for nitrogen fixation in the chemosynthetic symbionts of a number of animal hosts. Until now, no nitrogen-fixing chemosynthetic symbiont was known from the marine environment. This discovery raises the intriguing possibility that some chemosynthetic symbionts provide a source of newly fixed nitrogen in the ecosystems their hosts inhabit. ‘Omics' also promises new insights into the genetic mechanisms of host-symbiont communication. We recently discovered a unique ‘arsenal' of toxin-like genes, resembling those from pathogens such as *Yersinia* and *Vibrio*, in the genomes of deep-sea mussel symbionts. We hypothesise that some of these toxin-like genes are involved in molecular communication with their hosts, and others protect their hosts against parasites. Symbioses are usually classified as either 'nutritional' or ‘defensive', therefore, a defensive role for these iconic nutritional symbionts would be surprising.

P3.162 PETERSEN, JO*; SCHUPPE, ER; FUXJAGER, MJ; Wake Forest University; *petejo13@wfu.edu*

Evidence for Specialized Calcium Trafficking in a Muscle that Controls Rapid Woodpeckers Displays

Many animals perform rapid display maneuvers in sexual and competitive interactions, and the ability to produce these physically demanding body movements often requires muscular adaptations. Constitutive changes to the expression levels of calcium trafficking proteins that help set muscle contraction-relaxation speeds, including sarco/endoplasmic reticulum calcium ATPases (SERCA) and parvalbumin (PV), may be one means of supporting this behavior. We examined this issue in downy and red-bellied woodpeckers by measuring mRNA levels of genes that encode SERCA and PV in the main muscle that mediates rapid drumming behavior (*longus colli ventralis*) and a second muscle that is not involved in drumming (*pectoralis*). Drums are atonal sonations produced when individuals repeatedly strike their bill against a resonate surface at ~15 Hz (strikes/second), and thus we hypothesize the SERCA and PV are expressed more abundantly in the *longus colli*, relative to the PEC. We also measured expression of these two genes in white-breasted nuthatches, a passerine that drills into trees to forage but not to generate social signals. Our data reveal that genes expressing calcium buffering and trafficking proteins are upregulated in muscles associated drumming behavior. This effect is especially pronounced when we examined PV, as it was expressed over 40-fold more in the woodpeckers' *longus colli*, compared to the *pectoralis*. These findings suggest that constituative upregulation of genes involved in muscular calcium signaling processes may support an ability to produce rapid drum signals.

P1.271 PETERSON, AN*; MCHENRY, MJ; Univ. of California, Irvine; *anpeter1@uci.edu*

The kinematics of predation by the red lionfish (Pterois volitans)

An invasive predator can be detrimental to an ecosystem by disrupting food webs and outcompeting native predators. The ability to invade may be enhanced by a superior capacity of an invasive predator to sense and feed upon naive prey. In order to test this idea, we have begun an investigation into the foraging behavior of the Indo-Pacific red lionfish (*Pterois volitans*), which has invaded coral reefs of the Western Atlantic. We recorded the kinematics of foraging and the escape behaviors of prey endemic to the Indo-Pacific under various light levels in order to replicated diurnal, nocturnal, and crepuscular conditions in a cylindrical arena. In daylight, prey actively roamed the arena while lionfish constantly tracked and attempted to pursue prey. Successful captures were rare and occurred when prey were positioned directly against the wall. In darkness, prey mainly hugged the arena walls and instead of closely tracking prey, lionfish prowled the arena, often swimming in concentric circles. Encounters occurred less frequently in darkness, but lionfish were more successful during these encounters. The change in light/dark swimming behavior of lionfish indicates a switch in hunting modes when visual cues are removed that may increase the capture rate for lionfish. These preliminary findings offer a basis for examining whether lionfish feature exceptional foraging behaviors when interacting with their endemic prey. We plan to use these interactions to compare foraging behaviors during interactions with naive prey endemic to the red lionfish's invasive range.

P1.110 PETRANEK, CJ*; DUENNES, MA; MARTÍNEZ, O; MÉRIDA, J; PINEDA, E; RACHOCKI, L; PARSONS, Z; LOZIER, JD; DILLON, ME; Univ. of Wyoming, Univ. of California, Riverside, Univ. de San Carlos, ECOSUR, Univ. of Montana; *chrispetranek@gmail.com*

Patterns of wing shape differentiation across elevational gradients in North American bumble bees (Apidae: Bombus)

Geometric morphometric analysis of wing shape can reveal morphological differentiation between insect populations, yet it remains unclear if such differentiation is due to genetic drift, or is an adaptive response to local environments. Environmental gradients often result in morphological differentiation among populations, and wing shape differs significantly among lineages of a widely distributed Mesoamerican species complex of bumble bees (*Bombus ephippiatus sensu lato*) which inhabit variable climates from 515m to 3555m above sea level. Comparative analysis of wing shape among populations of bumble bees found across similarly broad altitudinal gradients at a range of latitudes in the western United States (*B. vosnesenskii* and *B. bifarius*) could provide new insights into widespread patterns of wing shape evolution in response to climate. Variation in environmental temperature across latitude and altitude can strongly influence wing size and shape, and reduced air density at high altitude may further constrain wing shape to maintain force production. We used a landmark approach to characterize wing shape of ~1200 bumblebees collected from 14 to 47°N latitude and from 49 to 3555 m asl. We discuss patterns of wing shape divergence congruent with altitudinal distribution as well as population structure. For instance, within Mexico two sympatric lineages occurring at interrupted altitude zones (~500m apart) show the greatest disparity in wing shape second only to two lineages occurring on opposite ends of the country (~2000 km apart over 10° latitude). Determination of the relative effects of phylogeny and local environment on wing shape across broad geographic scales provides insights into the evolution of insect flight morphology.

33.5 PEZOLD, F.L.; FORD, K.L.*; SCHMIDT, R.C.; Texas A&M University- Corpus Christi, University of Louisiana, Lafayette, Mpala Research Center, Smithsonian Institute, Kenya; *klf8880@louisiana.edu*

A New Species of Killifish (Cyprinodontiformes: Nothobranchiidae) from Liberia, West Africa

A new species of African killifish is described from specimens collected in tributaries and creeks in Sinoe County, Liberia, West Africa during 2014. It possesses the throat and lower jaw morphology distinctive for the genus *Epiplatys*. The species is diagnosed by bright orange body coloration, yellow median fins, red spots on the median fins and trunk, and with faint chevrons along the posterior half of the body. A distinct patch of blue color appears on the cheek and the head extending from just behind the eye to just above the pectoral fins. The species has been known to the aquarium trade as "Orange Liberia" and was originally collected from a single locality in Lofa County near the border with Guinea.

P3.253 PFEIFFENBERGER, JA*; SUMMERS, AP; Temple University, University of Washington, Friday Harbor Labs; *jpfeiffe@temple.edu*

Scaling and Morphology of the Armor in the Northern Spearnose Poacher, Agonopsis vulsa

Adult northern spearnose poachers (*Agonopsis vulsa*), like other poachers, are heavily armored, lack swimbladders, and live on the seafloor. However, as juveniles they spend a considerable amount of time in the water column and appear to be quite flexible. We investigated the scaling relationship of bone mineral density (BMD) and the volume of dermal armor plates, and measured the ability to resist compression changes through ontogeny. We hypothesized that (I) BMD and volume of dermal armor would scale isometrically with body size (0 and 3, respectively), and that (II) compressive load resistance would increase with body size. Fifteen *Agonopsis vulsa* (13 - 180mm SL) were collected and either micro CT imaged (N=9) or compression tested (N=6). Micro CT scans were performed with two objects of known densities of calcium phosphate hypoxyapatite (25% and 75%). BMD and volumes were measured on each fish and linearly regressed against body size. For compression testing, specimens were sectioned into 9 segments and compressed to 40% segment width (3 fish dorsoventrally, 3 fish laterally). We found that BMD scaled positively allometric with body size (Slope = 0.4) whereas volume of the armor scaled isometrically (Slope = 2.827). Dorsoventral compressions were inconclusive due to high variability in compressive forces, yet lateral compressions demonstrated scaling patterns and regions of increased compressive force resistance. Internal structures, such as the ribs, neural processes, and pterygoids appear to act as struts, resisting compression. CT scans of crushed segments reveal that armor plates appear to be locked in position, as the plates didn't slide past each other during compression.

114.4 PFEIFFENBERGER, JA*; HSIEH, ST; CZIKO, PA; CHENG, CHC; Temple University, University of Oregon, University of Illinois; *jpfeiffe@temple.edu*

The pelvic morphology of a bottom-walking Antarctic barbeled plunderfish, Histiodraco velifer, and how it compares to other Antarctic notothenioid fishes

While most fish use their fins for swimming, some benthic fish use their fins to "bottom-walk" on the seafloor. This particular form of locomotion is believed to allow them to remain cryptic while approaching prey or to avoid predation. The underlying morphologies that enable fish to bottom-walk are not well-described. The Antarctic plunderfish, *Histiodraco velifer* uses synchronized pelvic fin movements to "walk", or punt, along the ocean floor. Like other notothenioid fishes, they lack swimbladders yet have less ossified bones which increases buoyancy. However, no other notothenioids are known to bottom-walk. The goal of this study was to compare the pelvic morphologies of three notothenioid fishes, and describe the underlying pelvic girdle morphology that enables bottom-walking in *H. velifer*. Three specimens each of *H. velifer*, *Trematomus bernacchii*, and *Gymnodraco acuticeps* were microCT imaged and their pelvic structures segmented. We found that these representatives of diverse notothenioid families display similar pelvic morphologies, including reduced ossification of the pelvic plates compared to other, non-notothenioid fishes. Notably, for all notothenioids examined the anterior and posterior portions of the pelvis are cartilaginous, lacking ossification, while ossification is increased where the pelvic fins attach to the pelvic plate. In comparison to the other notothenioids, *H. velifer* has an elongate pelvis, which may allow for increased muscle attachment surface area to power the bottom-walking behavior. In all species, pelvic fin rays were more ossified than the pelvic structures and displayed an enlarged dorsal process for muscle attachment.

S6.11 PHELPS, SM*; GIGLIO, E; BURKHARD, T; University of Texas at Austin, University of Texas at Austin ; *sphelps@mail.utexas.edu*

Sing Out Loud: A Signaler's Perspective on Condition Dependence

The elaborate displays used in courtship and aggression are among the most diverse and striking phenotypes in animal behavior. Such extravagant traits impose costs, and signalers often adjust effort to reflect body condition. Tremendous effort has gone into understanding whether females use these traits as proxies for male condition. Remarkably little work, however, has asked what condition is, and how it is used to inform signaler decisions. We use a novel mammalian model, the singing mouse, *Scotinymys teguina*, to investigate these questions. Singing mice live in Central American cloud forests, and make elaborate trills used in mate choice and male-male competition. In natural populations, we examined a broad range of morphological and physiological markers, including residual body mass, circulating fats and sugars, and plasma levels of hormones known as adipokines. We find that measures of condition fell into two major orthogonal axes - one corresponding to short-term nutrient fluctuation, the other to long term body condition (adipokines, residual body mass). Plasma leptin, which is released by fat cells, was associated with measures of song effort. In the lab we manipulated perceived body condition by blocking fatty acid oxidation with 2-mercaptoacetate (2MA). 2MA increased feeding and foraging behavior, but significantly reduced song effort. Among 2MA-treated males who did sing, songs changed significantly in structure, including increases in internote intervals and reductions in frequency modulation. To examine the neural mechanisms by which condition could influence social response, we injected pseudorabies virus into the larynx and traced its innervations to brain regions relevant to aggression, mating and energy balance. Current work seeks to refine these relationships through immediate early gene studies and functional genomics.

S5.10 PHILLIPS, Caleb D*; HANSON, J. Delton; WILKINSON, Jeremy E; KOENIG, Lawrence; REES, Eric; WEBALA, Paul; KINGSTON, Tigga; Texas Tech University, Lubbock Texas, RTL Genomics, Lubbock Texas, 4Department of Tourism and Wildlife, Maasai Mara University, Narok, Kenya; *caleb.phillips@ttu.edu*

Microbiome Structural and Functional Incongruence across Host Dietary Niche Space

Host-associated microbiomes are an integral component of host health and function. Recent work elucidates this association and the large variation in microbiome community structure among hosts. Reconciling the extent of community variability with the apparent dependence of hosts on community function, as well as characterizing how functional divergence proceeds across niches, remains challenging. Here, through the study of digestive microbiomes of three insectivorous bat species we characterize how community structure is shaped by functional properties of community members. We use a novel inference framework to show that discordance between levels of community structural and functional variation is influenced by the continuum of shared and derived gene sets across microbial phylogeny. Through multivariate matrix comparisons we demonstrate that while host diet and microbiome community composition do not clearly relate to each other, host diet and metagenome function significantly correlate. We suggest that this discrepancy derives from functional equivalence among microbial lineages. Functional differencs among this set of insectivorous host species disproportionately occurs through selection on abundances of relatively derived microbial functions, as opposed to those that are phylogenetically widespread. Our findings suggest that selection and deterministic processes may influence community assembly, and provide a quantitative foundation for determining community structure-function assembly relationships.

P1.256 PHILLIPS, N; NAKATA, T; WALKER, SM; BOMPHREY, RJ*; Royal Veterinary College, Chiba University, Oxford University; *rbomphrey@rvc.ac.uk*

Aerodynamic Imaging by Nocturnal Mosquitoes

Nocturnal mosquitoes exhibit a behavioural response to divert away from surfaces despite visual cues being unavailable, indicating a short-range, non-visual collision avoidance mechanism. We hypothesised that this is mediated by mechanosensory feedback, with mosquitoes detecting and reacting to modulations of their own induced aerodynamic field as they enter ground or wall effect. We investigated the sensory information available for the putative mechanism using computational fluid dynamics of low-altitude and near-wall mosquito flight. Our simulations are based on detailed 3D wing kinematics extracted from high-speed recordings of free flying *Culex quinquefasciatus* mosquitoes. Our results reveal areas of relative pressure changes surrounding the body and head that are associated with close proximity to the ground and wall planes. The pressure modulation could provide useful information to the flight controller: a mechanism we term ‘aerodynamic imaging'.

P2.132 PHILSON, C.S.*; XU, A.; ELLERY, M.; RAY, A.; FOLTZ, S.L.; DAVIS, J.E.; Radford University; *CPhilson@radford.edu*

The PASSER Project: Development of micro-computer enabled feeders and nest boxes for songbird ecobehavioral research

Ecobehavioral research on wild songbirds has generally been conducted through direct first-hand observation of birds in the field. Here we describe preliminary results of the Programmable Automatous System for Songbird Ecological Research (PASSER) Project: an attempt to use computerized fabrication practices to develop low cost, field-ready, micro-computer enabled units capable of conducting many of the observational and environmental tasks of a field researcher. Our overall goal in this work is to develop equipment that can reliably and independently collect environmental and behavioral data for long periods of time without direct control or monitoring by the researcher. When fully emplaced the network will produce multi-modality data sets. In pursuit of this goal, we worked to develop both a nest box and a feeder. The initial nest box is fitted with internal and external environmental sensors and video cameras. It is also solar powered, contains a servo door that can shut remotely allowing the field researcher to capture the bird easily, has microbial swab emplacements for collecting samples from the residents, and generates a Wi-Fi network to allow for remote uplink and monitoring. Similar to the nest box, feeders are capable of recording ambient temperature and humidity. However, they also contain a pressure activated feeding pad to trigger video and audio recording of feeding activity. In addition, the feeder has a touchscreen located prominently adjacent to the feeding pad to facilitate interaction between bird and feeder, such that birds perform tasks in exchange for a food reward. Here we present both the design and development of these units, as well as preliminary data demonstrating their efficacy and potential uses.

P3.46 PICCIANI, N*; KERLIN, JR; SIERRA, NW; CANNON, JT; DALY, M; RAMIREZ, DM; OAKLEY, TH; UNIV. OF CALIFORNIA, SANTA BARBARA, THE OHIO STATE UNIVERSITY; *natasha.picciani@lifesci.ucsb.edu*

Cnidaria and Xenacoelomorpha Opsins Revisited: Extended Sampling Corroborates the Presence of Several Major pre-Bilaterian Groups

Opsins are photosensitive proteins widely used for light sensing in animals. Opsin diversity in non-Bilaterian animals is key for our understanding of this gene family's evolution and the evolution of eyes and light sensitivity. Nonetheless, opsins in non-Bilaterians are poorly known. Previous work with comparatively limited taxon-sampling suggested that cnidarians express three ancient opsin subfamilies (Anthozoa II, chaopsins and xenopsins - which includes the well-established cnidops). Opsin genes from representatives of Xenacoelomorpha (the sister group to other bilaterians) have not been studied so far. To improve taxon sampling of opsin studies, we screened publicly available and newly generated transcriptomes from 35 cnidarians of all major groups (except for Staurozoa), and 4 xenacoelomorphs. Following the protocol described in Ramirez et al. (2016), we retrieved 106 cnidarian and 17 xenacoelomorph opsin sequences. We corroborate that cnidarians consistently express opsins belonging to the groups Anthozoa II, Chaopsin and Xenopsin (Cnidops) as recognized by Ramirez et al. (2016). Like Anthozoa II opsins, cnidarian chaopsins are also only expressed by anthozoans.We show that multiple ancient gene duplications and losses of cnidops paralogs occurred during cnidarian history. Xenacoelomorphs express non-canonical r-opsins similar to those found in other bilaterians. Besides strongly supporting recently recognized opsin groups, our extended dataset provide further insights into opsin evolution in non-Bilaterian animals.

P2.27 PIERCE, NT*; NAVARRO, MO; GAASTERLAND, T; BURTON, RS; University of California, San Diego, University of Alaska Southeast; *ntpierce@ucsd.edu*

Effect of low pH and low oxygen conditions on developmental gene expression and hatching of Doryteuthis opalescens embryos

Eastern boundary upwelling systems (EBUS) are productive ecosystems that support as much as one-fifth of global fish harvest and are highly vulnerable to climate change. As a result of naturally-high CO2 (low pH) conditions, EBUS have a reduced capacity to buffer against changes induced by the uptake of anthropogenic CO2. The California market squid, *Doryteuthis opalescens*, represents one of the most ecologically and economically important species in the California Current system. While adults are highly mobile, developing *D. opalescens* embryos are attached to the substrate and must be able to survive fluctuations in environmental conditions during development. To investigate the effects of low pH and low oxygen on squid development, embryos were harvested in La Jolla, CA and reared in replicate flow-through seawater tanks of ambient (control; 240 µmol/kg O2, pH 7.95) and low-pH, low-O2 (low pHOx; 90 µmol/kg O2, pH 7.55) until hatching. These conditions represent the limits of pHOx observed in squid spawning habitat. Embryos exposed to low pHOx upregulated stress-response and oxygen-sensitive genes, and altered expression of genes associated with cell-cycle regulation, development and lipid utilization. Embryos exposed to low pHOx conditions also experienced an 11% increase in incubation time and 4% decrease in hatching success. These results suggest that exposure to chronic low pHOx, even within ranges typically found in the environment, represents a physiological stress for *D. opalescens* embryos. Understanding the mechanisms that enable developmental resilience to variable environmental conditions, and their limitations, will be important for predicting EBUS organismal response to future climate change.

P2.46 PIERRE-PIERRE, EN; CONGDON, ER*; JOHNSON, MA; Bethune-Cookman University, Trinity University; *congdone@cookman.edu*

Gender differences in tail autotomy in Anolis lizards

Predation is a major threat to the survival of most animals, and many mechanisms have evolved that allow an animal to escape a potential predator. One particularly interesting escape mechanism in reptiles is caudal autonomy, where a lizard voluntarily sheds its tail. This generally occurs when stress (such as that from a grasping bird beak) is placed on the tail, which detaches from the body along any one of multiple breakage planes, resulting in minimal injury to the animal. Broken tails often twitch violently, distracting the predator and allowing the prey to escape. Most lizards can regrow an autotomized tail, but this has been hypothesized to be energetically expensive. Quinn et al 2014 collected individuals from the Daytona Beach area and demonstrated through experimental trials that females experienced no significant loss of fitness when their tail was autotomized and did not forgo tail regrowth for the sake of reproduction. These results led to additional questions regarding the likelihood of individuals to drop their tails based on gender and breeding season. Given that tail regrowth appears to be minimally costly, we would expect males and females to have similar likelihoods to drop their tails when presented with a predator. Behavioral observations made in the summer of 2015 suggested that males may be more likely to drop their tails than females, but the sample size was small. We hypothesized that this difference may be due to the need for males to engage in riskier behaviors during territorial defense that increase the likelihood that they encounter a predator. This hypothesis was tested by capture and release of individuals to determine if they had experience tail autotomy in the past. We hope to use this information to further the body of knowledge on the costs and benefits of both territoriality and tail autotomy.

P3.166 PIGG, VA*; CHAMPAGNE, AM; ALLEN, HC; WILLIAMS, JB; University of Southern Indiana, The Ohio State University, The Ohio State University; *vapigg@eagles.usi.edu*

Effects of ambient temperature on the organization of lipids of the avian stratum corneum

The stratum corneum (SC) is the outermost layer of skin in birds, and is composed of corneocytes embedded in a matrix of lipids. These lipids are arranged in phase states ranging from highly ordered orthorhombic phase to a more disordered liquid phase. The specific phase state of lipids in the SC may determine the rate of cutaneous water loss (CWL), with the orthorhombic phase providing the greatest barrier to water loss, whereas more disordered phases allow for higher rates of water permeation. In this study, we captured House Sparrows (*Passer domesticus*) in winter and summer in central Ohio. After isolating the SC, we used infrared (IR) spectroscopy to assess the phase state of SC lipids from 25 to 50°C. Analysis of the CH_2 scissoring region revealed that lipids in the SC of birds exist predominantly in the orthorhombic phase at these temperatures and only a subset of lipids change phase as temperature increases. This minor phase change corresponds with the minor increase in CWL observed in passerines as temperature rises. Additionally, our results imply that lipids in the skin of some birds are more robust to temperature changes than lipids in mammalian SC, suggesting a fundamental difference in lipid organization.

S7.1 PISANI, D; University of Bristol; *davide.pisani@bristol.ac.uk*

Problems and progresses in Ecdysozoan relationships: do we have an emerging consensus?

Ecdysozoa represent one of the three main lineages of bilaterally symmetrical animals. The oldest, confirmed, fossil evidence of bilateral animal activity is represented by the ~541 million of years old feeding traces of an ecdysozoan (the priapulid worm like animal - *Treptichnus pedum*), and since then ecdysozoans have consistently dominated the phanerozoic ecosystems. To date, ecdysozoans constitute the largest majority of animal biodiversity (with the phylum Arthropoda), and animal body mass (with the phylum Nematoda). Ecdysozoans are of fundamental scientific importance as this lineage include the genetic and development model systems (the fly *D. Melanogaster* and the worm *C. elegans*), from which most of our knowledge of phenotype-genotype mapping stems. Understanding ecdysozoan evolution is fundamental to clarify the origin and evolution of extant animal biodiversity. However, to be able to correctly answers fundamental questions in ecdysozoan evolution, e.g. was the last common ecdysozoan ancestor segmented? We first need to clarify ecdysozoan relationships. Here, I shall summarise currently knowledge in ecdysozoan phylogenetics and present new results bearing on our understanding of the relationships and divergence times among the ecdysozoan phyla. I shall contend that while in most cases there is agreement between scholars, the relationships of some fundamental ecdysozoan phyla (like the Tardigrada - water bears) are still unclear, and will need further investigations.

18.1 PISANI, D; University of Bristol; *davide.pisani@bristol.ac.uk*

Improving the fit of the model to the data strenghten support for sponges as the sister group of all the other animals

There is significant disagreement on the phylogenetic relationships at the root of the animal tree of life. While initial analyses of genomic-scale datasets associated with the publication of the first two, completely sequenced, comb jellies (phylum Ctenophora) genomes (Ryan et al. 2013; Moroz et al. 2014; and Whelan et al. 2015) suggested that this lineage might represent the sister group of all the other animals, further re-analyses of the datasets associated with these studies (Pisani et al. 2015) showed that a position of the ctenophores at the root of the animal tree is most likely a tree reconstruction artifact. The results of Pisani and collaborators sparked a heated debate (e.g. Halanych et al. 2016 Vs Pisani et al. 2016) with Halanych et al. (2016) suggesting that, contrary to Pisani et al. (2015), the placement of the sponges at the root of the animal tree might represent a compositional attraction between Silicean sponges and the outgroups. Here, we will present results of reanalyses of all recently published datasets (Whelan et al. 2015; Chang et al. 2015; Cannon et al. 2016; Zapata et al. 2016) that bears on this problem and show that contrary to Halanych et al. (2016) correcting for compositional heterogeneity invariably strengthen support for sponges as the sister group of all the other animals. This strongly confirms the results of Pisani et al. (2015), and illustrate the pitfalls associated with the use of models (like the simple GTR+G, or multiple GTR+G) that do not account for all forms of heterogeneity in the data.

49.3 PITTOORS, NC*; LEONARD, JBK; Northern Michigan University; *npittoors@gmail.com*

Effects of pH and temperature on the harpacticoid Tisbe biminiensis growth, survivorship, and morphology

This study investigated the effects of climate change related environmental variation on growth, survivorship, and morphological plasticity of the harpacticoid copepod *Tisbe biminiensis*. Three experiments were conducted to determine the response to altered pH and temperature. Individuals were reared in laboratory conditions, in artificial seawater at combinations of one of two temperatures conditions (25°C and 34°C), and at either ambient or future pCO2 conditions (~400 utm and ~1000 utm). Post-hatch measurements for growth and morphology were obtained at intervals of twelve hours for subsamples of the cultures with data collection using microscopy and thin plate spline morphometric techniques.

59.7 PLAKKE, M.S.*; LOMBARDO, J.B.; PACELLA, G.I.; MESLIN, C.; CLARK, N.L.; MOREHOUSE, N.I.; University of Pittsburgh; *mep115@pitt.edu*

Investigating Digestive Properties of Reproductive Proteases in a Female Butterfly

Reproductive traits provide extreme examples of diversity due to the rapid rate at which they evolve. This diversity has been heavily explored in relation to male reproductive traits. However, increasing evidence suggests that female reproductive traits are similarly diverse yet remain understudied. In order to fully understand the coevolution between male and female reproductive traits, both sexes must be considered. Butterflies provide an excellent system in which to explore the coevolution of reproductive traits. Female butterflies have a specialized reproductive organ, the bursa copulatrix, which receives and processes the male ejaculate or spermatophore. One bursal function is to digest spermatophore proteins, which are subsequently used to fund egg production. Our previous work uncovered a cocktail of proteases in the bursa of the Cabbage White butterfly, *Pieris rapae*, which are hypothesized to digest the spermatophore. However, although two of these proteases are predicted to have trypsin-like proteolytic activity, this mode of action remained uncharacterized. We assessed the specificity of these trypsin-like proteases using a modified zymogram technique. We found that while the bursa exhibits activity similar to that of trypsin, a trypsin specific inhibitor fails to inhibit activity of bursal enzymes. Predictive structural analysis indicates that the active sites of the bursal enzymes resemble that of trypsin, while the amino acids responsible for specificity share little similarity, potentially explaining the lack of inhibition. By characterizing the specificity and activity of bursal enzymes, the interaction between the bursa and spermatophore can be further studied in the light of coevolution.

35.7 PLYLAR, H.B.*; GUTIERREZ, A; GRACE, M.S.; Florida Institute of Technology; *hplylar2015@my.fit.edu*

How Cool Is This?! Evaporative Heat Loss & the Snake Infrared Imaging System

Respiratory evaporative heat loss generates a "cold-nose" effect in snakes, indicated by a stark difference in temperature between the rostrum and body. This phenomenon is implicated in thermal targeting in snakes that utilize infrared imaging (i.e., rattlesnakes, and by extension possibly other pit vipers, and boas and pythons). These snakes possess facial pit organs that detect the heat generated by infrared photons, and transmit this information via a unique neural pathway to the brain's optic tectum. Once there, images of the thermal environment merge with visual images for more effective predatory and defensive targeting. Just as cooling augments the sensitivity of some artificial IR-imaging cameras, cooling of snake pit organs may enhance the quality of the image produced by lessening the effects of thermal background noise. As an initial approach to better understand the role of rostral cooling in snakes, we hypothesized that rostral cooling is more anatomically expansive in snakes possessing infrared-imaging systems than in those without IR capabilities. To test this hypothesis, we utilized infrared thermography to examine a variety of species of boid, crotaline, and colubrid snakes. We then used data generated from IR thermograms to measure and describe the extent of surface cooling relative to pit organ location, as well as the variation between species. Results show that (1) rostral cooling is common in both IR-imaging and non-IR-imaging snakes, (2) the anatomical extent of rostral cooling varies between species, (3) cooling encompasses the facial areas including the pit organs, and (4) cooling is more expansive in pythons relative to boas. This may provide enhanced thermal detection capabilities in some taxa for more effective detection and localization of homeothermic prey and potential predators.

89.2 PODOLSKY, RD; College of Charleston; *podolskyr@cofc.edu*

pH Gradients in Egg Masses of 11 Gastropod Species Reflect Chronic Exposure to Acidified Conditions during Encapsulated Development

Marine species that develop calcified structures during early development may be especially vulnerable to ocean acidification (OA). Although free spawning is common, species in several taxa undergo early development inside encapsulating structures. These structures could potentially buffer against effects of OA as they do against other environmental risks. On the other hand, embryos developing inside such structures may generate low internal pH as a byproduct of respiration. I used a microelectrode to measure pH gradients inside gelatinous egg masses of 11 species of gastropods. These species differed in egg mass design (strings, ribbons, and globose forms) and thickness (minimum dimension for diffusive exchange of gases and ions). Central pH in egg masses was highly variable across species, ranging from 7.77 to as low as 6.49 (for masses held at pH = 7.82). As expected, older embryos generated lower internal pH and steeper pH gradients, reflecting increased metabolism and CO2 production. Although globose masses were thicker and developed lower central pH, they had shallower pH gradients than ribbons, reflecting the effect of gel in spacing embryos and reducing pH stress in parallel with its effect on reducing oxygen stress. Egg masses held in acidified seawater (approx. pH = 7.42) exhibited slightly lower central pH but shallower pH gradients, suggesting that embryos were somewhat buffered from an external drop in pH. These results indicate that encapsulated embryos may experience chronically low pH and that egg mass design influences the degree of pH depression. As a result, encapsulation could lead embryos to evolve resilience to low pH and to future OA conditions. I will discuss this potential for pre-adaptation in light of the developmental performance of encapsulated embryos under elevated CO2 as presented in a separate poster.

P2.105 POLETT, ME*; GIFFORD, ME; University of Central Arkansas; *mpolett1@cub.uca.edu*

The Influence of Maternal Stress on Phenotypic Variation in Sceloporus consobrinus

Maternal effects of stress have been found to contribute to offspring phenotype and potentially influence offspring survival and fitness in many different species. Specifically, stress hormones like corticosterone (CORT) contributed by the mother in an embryonic environment have been shown to influence offspring morphology, growth, physiology, and behavior. Current studies are inconclusive as to the impact CORT has on offspring "personality" and how CORT can differentially impact the development of males and females. Using prairie lizards, *Sceloporus consobrinus*, as a model, we determined how exposure to CORT in the embryonic environment influenced offspring morphology, growth, stress response, and boldness. We expect to find significant phenotypic differences between treatments, but the direction of predicted phenotypic changes is unclear. Preliminary data indicate sex-specific differences hatchling body size among treatments as well as potential differences between early versus late clutches. These results will provide important clues to understand both short term and long term impacts of embryonic stress. These results will also provide a baseline for developing additional studies aimed at uncovering the cellular and molecular mechanisms involved in translating maternal hormonal effects into offspring phenotypes.

127.5 POLICH, R/L*; BODENSTEINER, B/L; ADAMS, C/I; JANZEN, F/J; Iowa State University; *rlpolich@iastate.edu*

Trangenerational effects of elevated corticosterone on offspring phenotype and fitness in the painted turtle (Chrysemys picta)

A major challenge facing conservation biologists is understanding the extent to which organisms can endure anthropogenic stressors such as habitat loss and global climate change. To clarify the effect of anthropogenic stressors on population viability, we simulated the effect of heightened maternal stress on offspring development in painted turtles. Exposure to the maternal stress hormone corticosterone (CORT) during embryonic development could influence developmental, morphological, and behavioral traits in offspring. We collected 20 clutches of painted turtle eggs and subjected them to three treatments: (1) low CORT (0.05ng/0.5µL), (2) medium CORT (0.25ng/0.5µL), and (3) high CORT (0.50ng/0.5µL). We incubated CORT-treated eggs in the field in a randomized block design. For each offspring, we recorded key traits such as body size and ability to right. Preliminary analyses indicate that treatment by CORT may affect embryos and hatchlings in several ways. Embryos in eggs treated with higher levels of CORT tended to incubate for a shorter period of time, produce hatchlings with shorter plastrons (proxy for size in turtles), or die prior to hatching. These traits have the potential to affect offspring fitness. Thus, this work may give insight into population viability of freshwater turtles experiencing anthropogenic stressors they have not evolved to endure.

91.4 POLLOCK, H/S*; BRAWN, J/D; CHEVIRON, Z/A; Univ. of Illinois, Urbana-Champaign, Univ. of Montana; *henry.s.pollock@gmail.com*

Testing the Microclimate Hypothesis: Thermal Physiology Does Not Explain Population Declines of Understory Birds in Neotropical Forests

Forest fragmentation is increasing in the Neotropics and has profound effects on bird communities. Certain guilds (such as understory insectivores and frugivores) are disproportionately vulnerable and experience population declines following forest fragmentation, and several hypotheses have been proposed to explain this phenomenon. The microclimate hypothesis posits that physiological sensitivity to novel microclimates in fragments is the mechanism underlying population declines of understory species. An important assumption of the microclimate hypothesis is that low climatic variation in the forest understory has selected for narrow physiological tolerances in these bird species, yet this assumption has never been tested. Describing patterns of variation in physiological tolerances among Neotropical bird guilds is thus an important first step towards establishing a link between thermal physiology and population-level responses to forest fragmentation. We measured the thermal tolerances of 83 Neotropical bird species to examine the relationship between species' ecology, thermal tolerances and population trends. Guild was not a significant predictor of variation in thermal tolerance breadth, and the tolerances of understory insectivores/frugivores were not significantly lower than other guilds. Furthermore, variation in tolerance breadth was not associated with species' population trends, contrary to the primary assumption of the microclimate hypothesis. Therefore, variation in thermal physiology is probably not responsible for the declines of understory species following forest fragmentation.

P1.28 PONG, S*; WALSH, P; ARMSTRONG, MK; CHRISTIE, AE; DICKINSON, PS; Bowdoin College, Univ. of Hawaii, Manoa; *spong@bowdoin.edu*

Variable Responses to Multiple Isoforms of a Neuropeptide, C-type Allatostatin (AST-C), by the Cardiac Neuromuscular System of the American Lobster, Homarus americanus

Central pattern generator (CPG)-effector systems, which are responsible for producing rhythmic movements, are controlled by anatomically fixed neural networks, which are nonetheless able to produce multiple patterns of movement. An important mechanism allowing such variability is modulation by neurotransmitters and hormones, many of which are neuropeptides. The lobster heart, which is controlled by a nine neuron CPG, the cardiac ganglion, is modulated by C-type allatostatins (AST-C), two of which [pQIRYHQCYFNPISCF, now AST-C I, and SYWKQCAFNAVSCFamide, now AST-C II] were previously known; both have previously been shown to modulate the lobster heart. Using transcriptomes generated from nervous system tissues, we identified a third isoform of AST-C, GNGDGRLYWRCYFNAVSCF, or AST-C III, in the lobster. All three AST-C isoforms consistently lead to decreases in contraction frequency when perfused through an isolated lobster heart; in contrast, all can elicit variable responses in contraction amplitude, with amplitude increasing in some lobsters and decreasing in others. Interestingly, the responses to AST-C I and AST-C III are more similar to one another than to AST-C II in any given lobster. We hypothesize that the differences in expression of AST-C receptors among individuals may cause these varying responses. Supported by: NSF (IOS-1353023, IOS-1354567), NIH (8P20GM103423-12), Cades Foundation, Doherty Foundation gift to Bowdoin College

67.3 POO, S*; CHUANG, M-F; KAM, Y-C; POO, Sinlan; Memphis Zoo, Tunghai University; *spoo@memphiszoo.org*

Predation Risk and Nest Site Value Determine Male Guarding Behavior and Reproductive Success

Predation is one of the main drivers of behavioral adaptations in preys. In species with parental care, predation can potentially affect the survival of both adults and their dependent offspring. This effect can be further modulated by other factors that contribute to mating and reproductive success of adults, such as the relative value of a breeding site. However, most studies looking at the direct effects of predation on parental investment and its carryover effects onto the next generation have focused on endothermic species, such as mammals or birds. We use male guarding behavior in a treefrog with paternal egg attendance to quantify effects of predation on adult behavior and subsequent effects on the survival of their offspring. Male behavior was determined by perceived predation threat and breeding site value, with more males abandoning low value sites when exposed to high risks. However, eggs in abandoned sites had lower hatching rates, and male return rate was positively correlated with clutch size. Results provide empirical evidence of how amphibian parental investment is affected by potential risks of predation and potential benefits of reproductive success, and how plasticity in adult behavior affects survival of their offspring.

P3.116 POOLE, AM*; MUSCEDERE, ML; Hendrix College, Conway AR; *pooleam@hendrix.edu*

Social Resilience and Behavioral Flexibility in Major Workers of the Ant Pheidole dentata

Polymorphism in social insect workers is often assumed to enhance division of labor but limit colony resilience in the face of environmental or social perturbations, since morphologically specialized worker subcastes (e.g. large major workers) general have specialized behavioral repertoires (e.g. defense). We investigated the ability of *P. dentata* majors to display behavioral plasticity when challenged with a task typically performed by their smaller minor nestmates (brood care), and tested a possible neuromechanism, biogenic amine signaling, that could influence task performance. We asked: (1) How does the performance and quality of brood care vary over one week in colonies where the proportion of major workers is higher than typical (ca. 10%); (2) are there costs to any behavioral compensation shown by workers in colonies with disrupted subcaste ratios; and (3) is plasticity of biogenic amine signaling a mechanism underlying behavioral compensation? Our results indicate that while brood condition suffered initially in colonies comprised entirely of majors, these majors largely compensated for the lack of minor worker efforts within 4-6 days by increasing their rates of foraging and brood-directed behaviors. Brood outcomes and foraging rates in colonies comprised of 80% majors were intermediate between 100% and 10% major colonies. While the time delay associated with behavioral plasticity in 100% major colonies is consistent with underlying physiological regulation, amine signaling did not appear to be strongly linked to our social perturbations. Our findings suggest that the ability of *P. dentata* major workers to flexibly contribute to brood care may be underestimated, and could buffer colonies from the potential costs of morphological specialization when caste ratios are disturbed.

12.1 PORTER, ML*; STECK, M; ROBINSON, HE; University of Hawai'i at Manoa; *mlporter@hawaii.edu*

The Kinematics of Larval Stomatopod Swimming and Strike Behaviors

Stomatopod crustaceans are well known for their predatory strike, which is one of the fastest recorded animal movements. In adult stomatopods, biomechanics of the rapid strike speeds of the raptorial appendages have been well studied. Larval strike behaviors, in comparison, have not been studied, although larval stomatopods also have raptorial appendage. We used high-speed video (1000 fps) to document the kinematics of larval strike speeds and swimming behaviors in squilloid and gonodactyloid larvae. In both types of larvae, antennal scales are used as rudders for stabilization during swimming. Differences between gonodactyloid and squilloid swimming behaviors include the resting position of the raptorial appendages; squilloid larvae hold the appendages out to the side while swimming, necessitating folding in the appendages before a strike is possible while gonodactyloids swim with the appendages already folded and ready to strike. The duration of larval stomatopod strikes (~3 ms) are similar to those recorded in adults. Because larval stomatopods are pelagic (in comparison to benthic adults) and unconstrained in space, specific body movements precede each strike, including bending the cephalothorax back and, for squilloid larvae, folding in of the stalked eyes. We also document that the very earliest gonodactyloid larval stages have only rudimentary raptorial appendages, and do not appear to be able to perform strikes, although at what stage larvae become capable of strike behavior is unknown. Continuing studies will identify larval species using barcoding, quantify strike speeds, and calculate Reynolds numbers for the extremely fast stomatopod larval strike.

63.2 PORTER, M/M*; RAVIKUMAR, N; HALL, G; HOLT, J/D; KAPADIA, A; WALKER, I/D; NEUTENS, C; ADRIAENS, D; Clemson University, Ghent University; *mmporte@clemson.edu*

Mechanical Evolution of Adaptive Designs in Biomimetic 3D-printed Structures and Robots

Modern prototyping methods, such as 3D-printing, provide convenient means to build reproducible physical models that mimic natural organismal designs for mechanical testing in controlled laboratory environments. Specific design modifications can be simplified or created to form idealized or hypothetical model systems with "adaptive" traits that can be individually tested and systematically compared. We use this approach to build "families" of biomimetic structures and robots inspired by the tails of syngnathid fishes (seahorses, pipehorses, and pipefishes), which are compared to test hypotheses on the adaptive evolution of their musculoskeletal systems. In this way, we subject the physical models to a variety of mechanical tests, quantify their response, and map their functional trade-offs. Upon comparison, it becomes clear how structural minutiae present in the tails of seahorses and related pipehorses provide them the unique ability to grasp.

P1.39 PORTER, ML*; CHAN, A; GUMM, JM; University of Hawai'i at Manoa, Stephen F. Austin State University; *mlporter@hawaii.edu*

The Evolution of Color Signals in Stomatopod Crustaceans

Stomatopod crustaceans have the most complex visual systems described in animals and display species-specific color signals used in aggressive interactions; yet very little is known about the evolution or function of coloration in these species. In particular, many stomatopods have species-specific colored patches on the inside of the raptorial appendages called 'meral spots' that are displayed in multiple behavioral contexts. To understand the drivers of diversity in signaling coloration of the stomatopod meral spot, we are investigating the patterns of color signal trait evolution in the genus *Neogonodactylus* (Stomatopoda, Crustacea). We have collected reflectance and genetic data from seven of the 22 described *Neogonodactylus* species. Meral spot reflectance spectra were used to determine the color of the meral spot, and to calculate standard color metrics including hue, brightness and chroma. Sequence data from five genes (COI, 16S, 18S, 28S, and H3) were used to create a phylogeny of the species, and comparative phylogenetic methods were used to evaluate patterns of color evolution. We used ancestral state reconstruction to look at the evolution of meral spot color. Our results suggest that closely related species tend to differ in color of the meral spot and that color evolved independently in clades found in both the Atlantic and Pacific. Continuing studies will estimate divergence times among species to date the timing of color changes.

P1.277 POTVIN, J*; WERTH, AJ; Saint Louis University, Hampden-Sydney College; *potvinj@slu.edu*

Oral Cavity Hydrodynamics and Drag Production in Balaenid Whale Suspension Feeding

Balaenid whales feed on large aggregates of small and slow-moving prey (predominantly copepods) through a filtration process enabled by baleen. These whales exhibit continuous filtration, namely, with the mouth kept partially opened and the baleen exposed to oncoming prey-laden waters while fluking. This filtration process is an example of crossflow filtration (CFF) in which most of the particulates (prey) are separated from the substrate (water) without ever coming into contact with the filtering surface (baleen). This poster will present the results of baleen filtration hydrodynamic simulations based on a type of hydraulic circuit modeling commonly used in microfluidics, but adapted to the much higher Reynolds number flows typical of whale hydrodynamics. This model uses as input the basic characteristics of the flows moving through a section of baleen observed in a previous flume study by the authors. Although of low-spatial resolution, the model fully incorporates the effects of fluid viscosity which, through the boundary layer enveloping the surface of each baleen, generates enough friction to at least double a whale's total body drag in comparison to non-feeding travel. Modeling viscous friction is crucial here since exposing the baleen system to the open ocean ends up tripling a whale's total wetted surface area. Among other findings, the model shows how CFF is enhanced by a large filtration surface and hence large body size; how it is carried out via the establishment of rapid anteroposterior flows transporting most of the prey-water slurry towards the oropharyngeal wall, along with substantially slower intra-baleen flows that transfer most of the substrate out of the mouth; and the general decrease in overall speed of both flows as they approach the oropharyngeal wall.

13.6 POWDER, KE*; ALBERTSON, RC; Clemson University, University of Massachusetts, Amherst; *kpowder@clemson.edu*

Identifying cis-regulatory enhancers associated with cichlid craniofacial evolution

Evo-devo theory posits that variation in *cis*-regulatory enhancers, which regulate the spatiotemporal pattern of gene expression, is a primary mechanism for morphological evolution. However, identifying relevant enhancers and characterizing their *in vivo* function remains a challenge. Recent studies in model organisms have experimentally identified >75000 enhancers active during facial, cartilage, and/or bone development. In order to identify which of these enhancers may mediate the unparalleled craniofacial variation that is a hallmark of the adaptive radiation of cichlid fishes, we utilized a bioinformatic approach. Specifically, we mapped enhancers experimentally identified in mammals to the tilapia genome, and cross reference these to both craniofacial QTL and genomic regions that exhibit high levels of genotypic divergence (i.e. high FST) among phenotypically divergent cichlid species. This approach prioritizes enhancers in an efficient and unbiased way from ten of thousands to dozens for functional assays. Using this method, we prioritized a putative *sox9b* enhancer that lies within QTLs for both lower jaw width and length and has fixed mutations in species that vary in jaw phenotypes. Using the CRISPR system in zebrafish, we show that genetic variation in the *sox9b* enhancer results in the highly specific loss of ceratobranchial cartilages as well as phenotypic variation in the lower jaw that mimics natural variation in jaw shape between cichlid species. We suggest that the bioinformatic integration of QTL and population genomic data from evolutionary models like cichlids with enhancer data from model organisms offers a powerful approach to both prioritize and functionally evaluate enhancers that may mediate morphological evolution.

101.5 POWELL, THQ; XIA, Q; DOWLE, E; FEDER, JL; RAGLAND, GJ; HAHN, DA*; University of Florida, University of Colorado - Denver, University of Notre Dame, University of Colorado - Denver; *dahahn@ufl.edu*

Rapid adaptation to a new seasonal regime drives genetic divergence and ecological speciation in the apple maggot fly Rhagoletis pomonella.

Divergent adaptation to seasonality, novel habitats, and niches can drive evolution of reproductive isolation between populations through the process of ecological speciation. Divergence in seasonal life history timing may be a particularly potent driver of ecological speciation for insects. In seasonal habitats, the timing of resource availability is a critical dimension of niche space for many specialist insects. Moreover, insect systems of mating often have a strong temporal component, resulting in a pleiotropic link between ecological divergence and reproductive isolation. Here we investigate the gene regulatory basis of seasonal life history divergence in a model system for ecological speciation, *Rhagoletis pomonella*, the apple maggot fly. The two host races in the classic *R. pomonella* system show strong differences in their adult eclosion phenology corresponding to phenological differences of their two host plants, downy hawthorn and domestic apple. This shift in life history timing is governed by the timing of pupal diapause termination, with apple flies terminating diapause sooner after the cessation of winter. Here we show differential gene expression between the host races upstream of known differences in diapause development. We report the results of an RNAseq study aimed at comparing the neuro-endocrine transcriptome of the two host races during diapause development, and we identify gene regulatory networks expressed in the earliest stages of diapause termination. Our results shed light on how insect life history timing evolves in nature and move us closer to being able to draw concrete connections between ecologically divergent phenotypes and patterns of genomic differentiation during seasonal adaptation.

62.4 POWERS, DR*; LANGLAND, KM; WETHINGTON, SM; TOBALSKE, BM; POWERS, SD; GRAHAM, CH; George Fox Univ., Newberg, OR, George Fox Univ., Newberg, ORe, Hummingbird Monitoring Network, Patagonia, AZ, Univ. of Montana, Missoula, MT, Stony Brook Univ., Stony Brook, NY; *dpowers@georgefox.edu*

Impact of Climate Change on Thermoregulation during Hovering in Hummingbirds

Flying animals generate large amounts of heat, which must be dissipated to avoid overheating. In birds, heat dissipation during flight is retarded by feathers, which cover most body surfaces. Heat dissipation is critical for hummingbirds who generate enormous mass-specific power during hovering. At moderate temperature (21°C) the thermal gradient allows hummingbirds to dissipate excess heat using heat dissipation areas around the eye, shoulder, and legs where feather density is reduced. However, predicted increases in environmental temperature resulting from climate change could decrease the thermal gradient needed for passive heat loss forcing reliance only on evaporation. In this study we used infrared thermography to measure surface temperature in hummingbirds at temperatures ranging from 15-48 °C to test how high environmental temperature impacts passive heat dissipation during hovering. Average body surface temperature positively correlated with environmental temperature from 15-38°C (environmentally controlled), but became constant at > 38 °C suggesting behavioral thermoregulation. Mean surface temperature of heat dissipation areas remained constant (~33°C) between 15-42°C suggesting integration with the body core. Thus, as environmental temperature increases, the thermal gradient for passive heat transfer decreases. When environmental temperature exceeds ~39°C the thermal gradient was reversed, causing an increase in thermal load. Predicted higher temperatures due to climate change could increase the risk of overheating during flight, thereby causing changes in foraging behavior and important social activities.

76.1 POWERS, SD*; MCTERNAN, MR; POWERS, DR; ANDERSON, RA; George Fox Univ., Newberg, OR, Western Washington Univ., Bellingham, WA; *seandpowers@gmail.com*

Energetic consequences for thermophilic lizards near the northern edge of the species' geographic range in the northern hemisphere

Lizard populations that live on the northern edge of their geographic range in the northern hemisphere encounter greater environmental variation relative to populations near the core of their range. For example, daily and seasonal activity lengths for northern populations are constrained by cooler environmental temperatures. It is unclear how individuals in these northern populations are able to profit energetically and persist in these cool climates. In this study, we investigated how individuals of *Sceloporus occidentalis* living in a cool, maritime climate in Washington state could profit energetically enough to permit persistence of the population. We also compared the energetics of these lizards to individuals from a warmer southern-and-inland population east of the Cascade mountains. During summer, we found no difference in total daily activity time or daily energy expenditure (DEE) between these populations. We also found no difference in field-active body temperatures (T_b) ($t_{1, 54}$ = 0.735, p = 0.466) or preferred T_b in the lab ($t_{1,43}$ = 0.548, p = 0.587). Prey availability, however, was 82% higher for the northern population. Northern lizards also consumed more food energy ($t_{1, 40}$ = 3.667, p<0.001). Northern lizards were 15% heavier relative to body length than lizards from the warm inland habitat ($F_{1, 110}$ = 11.8, p<0.001). We infer that despite a shorter activity season for the coastal population and similar etho-physiotypes (preferred T_b and DEE) between populations, the higher food availability and sufficient sunny weather during the summer on the coast permits enough individual activity and production to allow the persistence of the northern coastal population.

70.6 POWERS, AK*; KAPLAN, SA; GROSS, JB; Univ. of Cincinnati, Cincinnati, OH; *krutzlaa@mail.uc.edu*

The Developmental Basis of Cranial Bone Fragmentation in the Blind Mexican Cavefish

The blind Mexican cavefish, *Astyanax mexicanus*, is a natural model for regressive evolutionary changes, such as complete eye loss, following cave colonization. An extant surface-dwelling form of this species enables powerful comparisons across complex traits. Cavefish also harbor cranial abnormalities, including fragmentation of intact bones into multiple elements. Fragmentation, first observed over 70 years ago, demonstrates radical asymmetry across the lateral axis of the face. To understand the developmental basis of bone fragmentation, we performed an intra-individual *in vivo* staining and visualization procedure. We compared normal growth of the third suborbital (SO3) bone in surface fish (n=16) with aberrant growth in cavefish (n=30) from the first appearance of ossification through mature bone development. Surface fish SO3 bones form from a single condensation of mesenchymal cells ("primary ossification center") directly inferior to the eye that expanded uniformly in an antero-posterior direction. Conversely, cavefish demonstrated primary and multiple secondary ossification centers, arising spontaneously throughout development. Some ectopic ossification centers resulted in distinct fragments, while others were absorbed by the larger SO3 element. Further, the number of ossification centers differed between left and right sides of the face in juvenile cavefish, reflecting the morphological asymmetry present in adults. In sum, surface fish display typical patterns of SO3 bone growth, while aberrant and asymmetrical ossification processes underlie fragmentation in cavefish. This work reveals dynamic changes to the cranial complex in cavefish, over life history, which arose in response to the extreme pressures of the cave environment.

111.5 PRADHAN, DS*; MA, C; SCHLINGER, BA; SOMA, KK; RAMENOFSKY, M; Univ. of California, Los Angeles, Univ. of British Columbia, Univ. of California, Davis; *dspradhan@ucla.edu*

ANDROGEN SIGNALING IN MUSCLE OF A MIGRATORY SONGBIRD

In preparation for long-distance migration, birds dramatically modify major aspects of their anatomy, physiology and behavior. Prior to migration, Gambel's White-crowned Sparrows (WCS) become hyperphagic, accumulate lipid stores, gain weight, and increase fiber size of the pectoralis (flight) but not gastrocnemius (leg) muscles. Mechanisms regulating muscle hypertrophy are unknown, but androgens, that are anabolic, might be involved; however, plasma testosterone (T) and 5-dihydrotestosterone (5α-DHT) levels are basal at this time. We hypothesized that local androgen signaling within muscle stimulates flight muscle hypertrophy prior to migration. As a test, male WCS were sampled for androgen signaling molecules across three stages of migratory preparedness: winter (February), prenuptial molt (March), and spring departure (April). Despite the fact that T levels were low and generally invariant in blood and muscle, T was detectable in all tissues at each stage of migratory preparedness. Interestingly, in both muscles, mRNA expression levels of androgen receptor (AR) and 5α-reductase Type 1 (converts T to 5α-DHT) increased dramatically at departure compared to previous stages. Thus increased synthesis of 5α-DHT as well as an increased sensitivity to active androgen may enable muscle tissue to utilize existing androgenic substrate to activate AR-dependent anabolic properties of muscle in preparation for migration. The magnitude of the changes in both AR and 5α-reductase Type 1 were greater in the pectoralis as compared to the gastrocnemius. These data suggest that hypertrophy of flight muscles are especially susceptible to this enhanced androgenic signaling to promote increased endurance and power for long distance flight.

P2.165 PRATT, B*; MOHREN, T; DEORA, T; NJONGE, A; DANIEL, T; Univ. of Washington, Seattle; *danielt@uw.edu*

Focal laser energy illuminates strain sensing in insect wings

Animals rely on multiple sensory modalities to accomplish challenging sensorimotor tasks. Insects use a combination of vision, olfaction, and mechanosensation to control their rapid and complex flight maneuvers. While flight control largely depends on visual feedback, visual processing speeds are often too slow to support rapid flight responses. As such, flying insects use the faster mechanosensory modes to facilitate rapid and dynamic responses to perturbations. In particular, insect wings serve this mechanosensory function. They are richly imbued with patches of bell shaped strain sensors called campaniform sensilla. How campaniform sensilla extract and process strain information remains an open question. To address this question, we focused on campaniform sensilla on the wings of the hawk moth, Manduca sexta. We recorded the neural response to band-limited white noise mechanical stimuli and identified single neural units via spike sorting methods. Simultaneously, we recorded the wing motion using multi-camera high speed videography and reconstructed the spatial and temporal patterns of strain associated with the mechanical stimulus. Using the thermosensitive property of the mechanosensors, we applied local laser heating to map the receptive region on the wing for each identified neuron. This novel technique allowed us to compute the local strains experienced by each sensillum. We found that these strain sensors encode mechanical information rapidly (spike timing precision of between 2 and 10 ms) and with high selectivity (preferentially encoding stimuli closely resembling particular stimulus features) This suggests wing strain sensing is a critical component of the control system in flying insects.

P2.207 PRECOPIO, LN*; BALES, KL; WILLIAMS, LE; Providence College, Univ. of California, Davis; *lprecopi@friars.providence.edu*

Inter-individual Variation in the Gut Microbiomes of Titi Monkey Family Groups

The gut harbors trillions of microbes, and we now know that health and development are influenced by these microbes. However, the relationship between the gut microbiome and the host is just beginning to be investigated in detail. Studies are establishing how the gut microbiome varies over time, between individuals and across physical states. We analyzed fecal samples from titi monkeys (*Callicebus cupreus*), which are New World, socially monogamous monkeys. As members of a laboratory maintained colony, the monkeys' genealogy is known, and their diet and environment are controlled. This allows us to explore the effects of genetic relatedness versus environment on gut microbiome structure and composition. To identify types of bacteria in the titi monkey gut microbiome, we extracted genomic DNA from fecal samples of 32 monkeys, including parents and offspring. We sequenced 16S rRNA amplicons using the Illumina MiSeq and then processed data using mothur to identify and quantify bacterial types, represented as operational taxonomic units (OTUs), in each fecal sample. We detected >118,000 sequences in each fecal sample and <3,400 in each negative control. Across all samples and negative controls, we detected 2,828 OTUs, which are groups of sequences that are 97-100% identical. The OTUs with the most sequences are *Prevotella*, *Acidaminococcaceae*, and *Treponema*. We are processing data to explore inter-individual variation and the impact of genetic relatedness on the types of bacteria present in the gut. The gut microbiome of titi monkeys has not been reported yet, and data from this project will contribute to our understanding of the diversity and variation of gut microbiomes in non-human primates.

47.3 PRESNELL, JS*; BROWNE, WE; University of Miami, FL, Smithsonian National Museum of Natural History, Washington DC; *jspresnell@gmail.com*

Kruppel-like factor function in the ctenophore Mnemiopsis leidyi suggests an ancient role in endoderm development

In bilaterians the Kruppel-like factors (KLFs) are transcription factors that play critical roles in stem cell maintenance and balancing aspects of both cell proliferation and differentiation. Information regarding KLF expression and function are lacking in earlier diverging non-bilaterian lineages. In this study we examine the molecular function of KLF orthologs in the lobate ctenophore, *Mnemiopsis leidyi*, using a combination of developmental expression analyses, immunohistochemistry, and targeted gene knockdown using two independent methods. The *Mnemiopsis* genome contains 3 KLF genes, *MleKlf5a*, *MleKlf5b*, and *MleKlfX*. MleKLF5a and MleKLF5b are closely related to bilaterian KLF5 and KLF4, which have been shown to play competing roles in proliferation and differentiation in the vertebrate gut epithelium. MleKLFX has no clear orthology to other metazoan KLFs. Here we show that *MleKlf5a* and *MleKlf5b* genes are expressed in tissues and organs derived from endoderm. Our functional work shows that knockdown of KLF orthologs in *Mnemiopsis* results in extensive endodermal patterning defects. These results suggest an ancient role for KLF transcription factors in mediating aspects of transcriptional regulation associated with endodermal patterning and differentiation in metazoans.

P3.147 PRICE, ER*; SIRSAT, TS; SIRSAT, SKG; DZIALOWSKI, EM; University of North Texas; *edwin.price@unt.edu*

A Test of the Membrane Pacemaker Hypothesis during the Ontogeny of Endothermy in an Altricial Bird

The membrane-pacemaker hypothesis proposes that membrane composition, particularly docosahexaenoic acid (DHA) content, functions as a controller of basal metabolism. We tested this hypothesis by altering the dietary lipid composition of red-winged blackbird hatchlings (*Agelaius phoeniceus*), predicting that supplemental DHA would incorporate into membranes and increase whole-animal and mitochondrial respiration rates. Beginning 1 or 2 days after hatching, nestlings were supplemented in the field with a daily oral dose (3% of body mass) of sunflower seed oil (high ω-6), fish oil (high ω-3, including DHA), or not supplemented (control). At 5, 7, or 9 days after hatching, we measured resting metabolic rate (in the thermoneutral zone and while decreasing ambient temperature to 15°C) and mitochondrial respiration using permeabilized fibers from pectoralis muscle. Dietary treatment did not have a main effect on metabolic rate (total, body-mass-specific, or pectoralis-mass-specific), but interacted with ambient temperature, such that differences among dietary treatments were apparent at low ambient temperatures but not in the thermoneutral zone. At all ages, birds that received the seed oil supplement tended to have higher VO_2 than those that received fish oil. In permeabilized muscle fibers, mitochondrial respiration rates did not differ between seed and fish oil groups, but sometimes were higher for these groups compared to controls. Our dietary manipulation failed to support the membrane pacemaker hypothesis. This could be due to strong effects of the diet on unmeasured variables, such as eicosanoid production. Alternatively, the membrane-pacemaker hypothesis might need refinement.

P1.140 PRICHARD, M.R. *; BREUNER, C.W.; University of Montana; *mackenzie1.prichard@umontana.edu*

Glucocorticoids and parental effort in tree swallows (Tachycineta bicolor)

Historically, elevated stress hormones are thought to suppress reproductive effort, as summarized in the 'cort-fitness hypothesis' and the 'cort-trade-off hypothesis.' However, that elevated glucocorticoids (GCs) during breeding can predict greater reproductive success. This increase in GCs might be associated with the increased metabolic demands of parental care and has been termed the 'cort-adaptation hypothesis.' Combining these three hypotheses describes two contrasting relationships between GCs and reproductive behavior. In order to more clearly understand how GCs predict parental behavior we observed several aspects of parental effort including feeding rates, nest attendance, defensive behavior and nestling growth rates in tree swallows (*Tachycineta bicolor*). We also evaluated both baseline and stress-induced GC levels during the mid-nestling phase. I will present on the relationship between plasma GCs and parental effort in order to help understand the discrepancies in understanding of GCs, stress, and parental investment.

115.5 PRITCHARD, CE*; CLINCHY, M; ZANETTE, LY; SHERIFF, MJ; Penn State Univ., State College PA, Univ. of Victoria, Canada, Univ. of Western Ontario, Canada; *cep197@psu.edu*

Direct and Indirect Predation Cues Affect Prey Foraging Behavior and Physiology

Predation is one of the central organizing themes in ecology. Predators may affect their prey through both direct predation (i.e. killing), and indirect predation (i.e. risk effects). Two important outcomes of risk effects are physiological and behavioral changes, with physiological changes mediating behavior to return the animal to homeostasis. However, rarely are these two outcomes studied in concert in wild animals exposed to chronic predation stress in the field. Here, we exposed wild deer mice to chronic predation stress in the field via aerial predator playbacks. After 18 days of exposure, deer mice continued to have elevated glucocorticoid levels and decreased foraging in predator-exposed vs. control grids. Foraging was also dependent on microhabitat, such that foraging further decreased in open areas compared to closed, highly vegetated areas. Our results suggest that behavioral shifts did not compensate for physiological changes and vice versa after 18 days. Further, physiological and behavioral changes may be codependent, and driven by multiple risk stimuli simultaneously, resulting in context-dependent antipredator behaviors of various magnitudes.

123.1 PRUETT, JE*; MAYERL, CJ; RIVERA, ARV; BLOB, RW; Clemson University, Creighton University ; *jep0057@auburn.edu*

Hind limb muscle function in turtles: is novel skeletal design correlated with novel muscle function?

Locomotor performance is fundamental to the ability of many vertebrates to survive and reproduce. Evolutionary changes in the attachments of a muscle can change its line of action, potentially altering its effectiveness in contributing to particular motions and overall locomotor performance. In cryptodire turtles, the hind limb muscles originate on the pelvis before inserting on the limb. In pleurodire turtles, derived fusion of the pelvis to the shell has caused the origins of many hind limb muscles to shift from the pelvis to the shell. To test the locomotor effects of these rearrangements, we measured hind limb kinematics, muscle moment arms, and muscle activity (EMGs), for representative aquatic generalist species of pleurodire (*Emydura subglobosa*) and cryptodire (*Trachemys scripta*) turtles in walking and swimming. We found that the hind limb muscles in pleurodires exhibited relatively greater mechanical advantage than those in cryptodires, primarily in abduction and adduction. Among muscles with different attachment locations between lineages, some (e.g., flexor tibialis internus) maintained similar activity patterns between taxa. However, other muscles showed differences in activity. For example, puboischiofemoralis internus (PIFI), which cryptodires use to protract the hip, exhibited a novel burst during stance in walking pleurodires. Due to the ventral shift of the origin of PIFI, we suspect this novel burst may stabilize or adduct the limb. Matching this prediction, pleurodires show greater hind limb adduction than cryptodires during both behaviors. Altogether, our results suggest that changes in attachment location can lead to changes in muscle activity, but such changes are not necessarily linked.

74.5 PRZYBYLSKA, AS*; WOJCIECHOWSKI, MS; DROBNIAK, SM; JEFIMOW, M; Nicolaus Copernicus Univ., Poland, Jagiellonian Univ., Poland; *annaprzybylska2808@gmail.com*

Photo-responding Siberian hamsters support the allocation model of the relationship between energy metabolism and activity

The population of Siberian hamsters (*Phodopus sungorus*) consists of individuals that differ in the response to seasonal changes. Responders, who are sensitive to shortening photoperiod, enter daily torpor in winter while non-responders remain normothermic throughout the year. We tested the hypothesis that these phenotypes differ in their behavior. We used 80 male and 80 female hamsters acclimated to winter-like conditions for 18 weeks. We also predicted that hamster behavior correlates with energy metabolism. To quantify behavior, we tested each hamster in an open field, and then measured its nest building activity. Both tests were repeated ten days apart. We used principal components analysis to define behavioral variables. Basal metabolic rate (BMR) was measured by indirect calorimetry and body temperature was monitored continuously with data loggers. Hamsters were classified into 3 phenotypes: those which entered torpor and changed fur to white were defined as responders, those which did not enter torpor and were gray were defined as non-responders, and those which only used torpor or only changed fur - as half-responders. Phenotype affected the difference between males and females in body mass-adjusted BMR ($p<0.01$); BMR of responding males tended to be higher than that of females, while among other phenotypes the opposite was true. We found a negative correlation between energy metabolism and exploration behavior ($p<0.05$) only among responders. This correlation supports the allocation model of the relationship between energy metabolism and activity in responders, but not in other phenotypes. The study was supported by the grant #NCN 2014/13/B/NZ8/04698.

P2.75 PRZYBYLSKA, AS*; WOJCIECHOWSKI, MS; JEFIMOW, M; Nicolaus Copernicus Univ., Poland; *annaprzybylska2808@gmail.com*

Behavior of photo-responding Siberian hamsters is not consistent among seasons

Animals living in a seasonal environment cope with changing biotic and abiotic conditions over lifetime. To be successful, they have to adjust their behavior and physiology to changing conditions. Siberian hamsters (*Phodopus sungorus*) acclimated to winter develop two phenotypes, one responding to seasonal changes, and the other not. In winter responders decrease body mass, regress gonads, change fur to white, and eventually enter torpor. We asked whether hamsters behavior also changes seasonally, and whether it shows consistent among-individual differences throughout the year. 80 male and 80 female hamsters were acclimated for ~3 months to summer and then to winter. Each season hamsters were tested twice in an open field and then their nest-building activity was measured. During 5 minute open field test we measured total distance covered, maximum speed, total duration of scratching the arena, rearing, grooming, wall climbing, time spent in the center of the arena or in the corners, or near the walls. Nest building activity was measured in hamster home cage as the extent of toilet paper tube destruction. Hamsters showed consistent among-individual differences in all measured behavioral traits; the repeatability ranged between 10 and 40% (in all cases $p<0.05$). However, when responders and non-responders were analyzed separately, a clear difference between these phenotypes emerged. Nine out of ten behavioral traits were consistently different throughout the year in non-responders, while in responders only half was repeatable. These results suggest that photo-responding hamsters develop winter phenotype which differs behaviorally from the summer one, and that behavior of non-responders is consistent throught the year. The study was supported by the grant #NCN 2014/13/B/NZ8/04698.

P3.133 PUDALOV, N*; ZIATEK, S; JIMENEZ, A.G.; Colgate University; *ajimenez@colgate.edu*

A Comparative Study of Bird Migration Patterns in Madison County and the Adirondack Region using Citizen Science

Migration represents a significant physiological challenge for birds and increasing ambient temperatures due to global climate change may add to birds' physiological burden during migration. We analyzed bird migratory patterns in a central New York county, Madison County, and two counties in the Adirondack Region, by using data from the citizen-science network eBird and correlating it to historical temperature data. Using linear regressions, we looked at different aspects of migration and how those patterns have been affected by temperature changes over the years of 2010-2015. Species of birds sighted in Madison County (N=195) and the Adirondack Region (N=199) were categorized into year-round, one-stopover and two-stopover groupings based on eBird observations. The maximum, minimum, and mean temperatures in Madison County, as well as the maximum temperatures in the Adirondack region have significantly increased over the past 45 years. There has been faster warming in the Adirondack region, making a comparative study of bird migration patterns in the two regions especially relevant. For one-stopover species, 53 species showed a change in the number of days they spent in Madison County and the minimum temperature they experienced while in the area. Adirondack Region species of birds also seem to display particular arrival date sensitivity to temperature changes, as 31 one-stopover Adirondack species arrived significantly later in the year. Links between temperature and migration events suggest that global climate change may have important effects on bird migration patterns through New York.

20.4 PUSCH, EA*; BENTZ, AB; NAVARA, KJ; University of Georgia; *epperfectchoice@gmail.com*

Personality corresponds to differences in immunity in two strains of laying hens.

Studies suggest that, in animals, personality type is correlated with the degree of stress responsiveness. For example, white laying hens are reactive, flighty, and exhibit large hormonal and behavioral responses to stress while brown laying hens are proactive, exploratory, and exhibit low hormonal and behavioral responses to stress. However, whether these "personalities" are also correlated with other physiological differences is unknown. The objective of this study was to determine if animals with different personality types also exhibit differences in immunity. We hypothesized that white hens, with reactive personalities, would show more dampened immune responses than brown hens due to their exposure to higher levels of corticosterone throughout life. To assess immune function in white and brown hens, we compared febrile responses to an injection of lipopolysaccharide (LPS) or saline, the inflammatory response to a PHA injection in the toe web, and innate phagocytic activity in whole blood collected from both strains. Contrary to our predictions, white hens had significantly greater swelling of the toe web in response to PHA injection than brown ($p=0.018$). There was no effect of treatment on the febrile response to LPS or saline injection. However, white hens showed a significantly greater reduction in egg production after LPS injection than brown hens and also had significantly greater plasma CORT levels after exposure to LPS than brown hens did, suggesting a larger sickness response overall.

P1.265 RADER, JA*; HEDRICK, TL; University of North Carolina at Chapel Hill; *jrader@live.unc.edu*

Flight performance of vultures across an elevation gradient

Animals must tune their physical performance to compensate for changing environmental conditions. The breadth of this environmental tolerance may, in turn, contribute to delineating the species' geographic range. A common environmental challenge that many animals face is life at high elevation, and its characteristic reduction in air density. Flying animals are particularly sensitive to this, as the effectiveness of their lift generation suffers in low air density. Compensation for lower density air must manifest in wing morphology, flight speed or increased power input. While some high elevation fliers have been shown to have relatively larger wings, and thus decreased wing loading (body mass / wing area), there has been less focus on whether and how fliers respond behaviorally. Turkey vultures (*Cathartes aura*) span a broad geographic range that exposes them to elevations ranging from sea level to >3000 meters. There is no evidence that vultures differ morphologically throughout their range, so they must compensate for air density differences by other means. We used 3-dimensional videography to track turkey vultures flying at two elevations (~120 m and 2200 m) to look for evidence that vultures fly faster at higher elevations, but otherwise exhibit similar gliding performance. After correcting for ambient conditions, we predicted that the high elevation birds would have a 14% faster airspeed, on average, than the low elevation birds, assuming that they are geometrically similar. We found that, indeed, high elevation vultures fly approximately 14% faster. However, the vultures did not differ in their sink rates, suggesting at least partial behavioral compensation for the elevational gradient. Our study highlights how field studies can illuminate the relationship between biomechanical performance and ecology.

131.3 RAEL, R C*; TAYLOR, C; Tulane University; *rrael@tulane.edu*

A flow network model of rat dynamics in New Orleans

Ecological and societal communities concurrently change and reassemble in response to one another following a traumatic event such as a natural disaster. This recovery process can potentially provide opportunities for commensal pest species to recover and spread quickly. Norway rats are common urban pests that can carry and transmit several zoonotic pathogens, posing a potential health risk to humans and domestic animals. Though they are globally widespread, little is known about how natural and human-related changes in urban landscapes affect the population dynamics and movement of this species. As part of an interdisciplinary project investigating recovery of human and natural systems in New Orleans, Louisiana after Hurricane Katrina, we are designing and implementing framework for modeling movement and dynamics of Norway rat populations across a spatially heterogeneous urban habitat. This model consists of a network of locations in which parameters of the population dynamics are determined by local conditions. I will describe how network structure relates to the likelihood and speed of network occupancy in an invasion or re-population scenario, and how local population densities relate to network neighborhood properties. I will also present model results that describe outcomes of applying strategies for controlling the spread of rats and rodent-borne diseases by altering properties of network nodes (locations), and edges (movement routes). Finally, I will describe how we are using extensive data being gathered on rat demographics and genetics through a trapping census study, ground cover vegetation data, and GIS data to parameterize movement and life history features in the model and explore hypotheses of gene flow and invasion across the New Orleans landscape.

S4.1 RAGLAND, GJ*; WILLIAMS, CM; U Colorado, Denver, UC Berkeley; *cmw@berkeley.edu*

Introduction to Evolutionary Impacts of Seasonality symposium

Organisms living in seasonal environments experience fluctuating selection pressures that influence their ecology and physiology, and drive their evolution. Classic work by Dobzhansky and early researchers identified seasonal fluctuations as a potentially important mechanism maintaining genetic polymorphism in natural populations, and studies of seasonal polyphenism and phenology have advanced our understanding of life history evolution. Recent advances in the field are moving towards greater understanding of the impacts of seasonality on genomic and physiological evolution, promising to illuminate the importance of seasonality in generating adaptation and constraining evolution. This symposium brings together experts from across disparate fields, with complementary expertise covering the entire span of the biological hierarchy and the breadth of terrestrial eukaryotes. The early morning session will cover functional and mechanistic responses, late morning session ecological responses, and evolutionary responses to seasonality will be in the afternoon session.

S4.9 RAJPUROHIT, S; TURCOTTE, M; PETROV, D; LEVINE, J; SCHMIDT, P*; University of Pennsylvania, ETH Zurich, Stanford University; *schmidtp@sas.upenn.edu*

Rapid Adaptation to Seasonality in Drosophila

In natural populations of the genetic model, *Drosophila melanogaster*, latitudinal clines have been widely observed. These patterns are commonly interpreted as evidence of natural selection and local adaptation, but the mechanisms and evolutionary dynamics that generate and maintain clines are largely unresolved. Many of the same environmental parameters that vary with latitude also vary predictably over seasonal time, allowing for a mechanistic dissection of rapid evolution in a genetic model. In temperate habitats, fly populations fluctuate seasonally, reaching peak abundance in late summer followed by a pronounced crash in fall. Prior work has demonstrated that these populations experience rapid adaptive responses to seasonality in replicate years. This occurs over approximately 10-15 generations (spring to autumn), and results in 1) a genomic signature of seasonal adaptation in which a non-random set of molecular variants cycle in frequency with season, and 2) predictable change in life histories and fitness-associated traits. In order to further address fundamental dynamics of rapid, seasonal adaptation, we performed field-based experimental evolution studies over three successive years. Our data demonstrate that natural Drosophila populations respond rapidly (within three generations) and predictably to specific environmental parameters in the field, and that the shifting selection regimes associated with distinct seasonal environments appears to maintain genetic and phenotypic variation in natural populations.

111.4 RAMENOFSKY, M*; PRIESTER, C; KOOPMAN, H; GAY, DM; DILLAMAN, R; Univ. of California, Davis, Univ. of North Carolina, Wilmington; *mramenofs@ucdavis.edu*

Biochemical and ultrastructural adaptations of avian flight muscle for long distance migration and arrival on the breeding grounds

Annually migratory birds express phenotypic flexibility in behavior, physiology and morphology that enable them to cope with dynamic changes in the energetic demands while progressing through each life history stage. In order for arctic bound migrants to perform long distance travel between wintering and breeding sites in spring, adequate fuel and power in flight muscles are required for sustained movements and resilience to the unpredictable conditions at high latitudes. In preparation for spring migration, Gambel's White-crowned Sparrow (WCS) increase food intake, deposit lipid in subcutaneous stores and exhibit flight muscle hypertrophy prior to departure. Others have confirmed lipid deposition is expedited by molecular mechanisms to promote fatty acid mobilization and utilization in flight muscle. Yet progression of the biochemical and ultrastructual changes in flight muscle throughout the transitions from winter (Feb) and spring departure (April) on wintering grounds to arrival on arctic breeding sites (May) are not known. Our results confirm that each of the 3 stages is unique with intramuscular lipid peaking at departure ($P<0.01$), predominance of unsaturated fatty acids at departure and arrival ($P<0.01$) and concentration of intramuscular mitochondria greatest upon arrival ($P<0.01$). These results illustrate the fine-tuned flexibility of migrants at the subcellular level focusing on capacity for deposition and production of energy as WCSs progress from sedentary conditions in winter to impending mobility of migration and adjusting to unpredictable conditions on arctic breeding grounds.

P3.101 RAMIREZ, A. F*; SMITH VIDAURRE, G; WRIGHT, T. F; New Mexico State University; *rmrzaldo@nmsu.edu*
Lower intraspecific aggression associated with lower genetic diversity in invasive urban colonies of the rough harvester ant Pogonomyrmex rugosus
Ants include some of the most successful and widespread urban invaders. Rough harvester ants (*Pogonomyrmex rugosus*) are found throughout urban habitats in the Southwest, likely as a result of invasion from neighboring rural areas. Founder effects following urban invasion are expected to decrease genetic diversity within colonies and increase genetic similarity between colonies, and thus lower intraspecific aggression. We conducted 350 trials comparing inter-colony aggression within and between urban and rural settings. In trials conducted between neighboring colonies, urban colonies displayed lower aggression than rural colonies. In contrast, urban and rural colonies showed similar levels of aggression towards non-neighbors from the same setting and across the two settings. We assessed genetic diversity within colonies using three microsatellite loci. Preliminary results for three markers and six colonies per setting indicate that urban colonies exhibit lower genetic diversity than rural colonies. These results suggest lower genetic diversity within neighboring urban colonies has led to lower intraspecific aggression among neighboring colonies.

36.2 RAMIREZ, MD*; OAKLEY, TH; Univ. of California, Santa Barbara; *ramirez@lifesci.ucsb.edu*
The kernels of major opsin diversity arose before the last common ancestor of all bilaterians
Opsins, the primary proteins animals use to sense light, have undergone a dramatic expansion since they originated early in animal evolution. Understanding the origins of opsin diversity can offer clues to how separate lineages of animals have repurposed different opsin paralogs for different light-detecting functions. However, the more we look for opsins outside of eyes and from additional animal phyla, the more opsins we uncover, suggesting we still do not know the true extent of opsin diversity, nor the ancestry of opsin diversity in animals. To estimate the number of opsin paralogs present in the last common ancestor of all bilaterians and Cnidaria + Bilateria, we reconstructed a reconciled opsin phylogeny using sequences from 15 animal phyla, including the traditionally poorly-sampled echinoderms and molluscs. Our analysis strongly supports a repertoire of at least nine opsin paralogs in the bilaterian ancestor and at least four opsin paralogs in the last common ancestor of cnidarians+bilaterians. Thus we have found a greater opsin diversity earlier in animal history than previously known. Further, opsins likely duplicated and were lost many times, with different lineages of animals maintaining different repertoires of opsin paralogs. This phylogenetic information can inform hypotheses about the functions of different opsin paralogs and be used to understand how and when opsins were incorporated into complex traits like eyes and extraocular sensors.

25.2 RANGE, R. C.; Mississippi State University; *range@biology.msstate.edu*
Evolution of Anterior-Posterior Axis Specification and Patterning: Insights from the Sea Urchin Embryo
The early specification and patterning of cell fates along the primary body axis of many metazoan embryos relies on a gradient of Wnt signaling. In most embryos this patterning mechanism depends primarily on high levels of localized canonical Wnt/Beta-catenin signaling around one pole of this embryonic axis, which will form endoderm/endomesoderm, and localized Wnt signaling antagonists around the opposite pole that typically aid in specifying the ectodermal and neuroectodermal territories. We have recently shown for the first time in any embryo that the sea urchin uses integrated signaling from three different Wnt signaling branches (Wnt/Beta-catenin, Wnt/JNK, and Wnt/PKC pathways) to pattern early neuroectoderm territories along the anterior-posterior axis. Here, we present new functional evidence suggesting that the three Wnt branches interact through several extracellular modulators (Wnt1, Wnt8, Wnt16, sFRP1/5, FrzB, Dkk1; Dkk3) and receptors (Fzl5/8 and Fzl1/2/7). Our data also suggest these Wnt branches also interact through intracellular transduction molecules (e.g. PKC, NFAT, and ATF2) and the transcriptional gene regulatory networks they activate. These data represent the first steps in our strategy to use a combination of high-throughput genome-wide assays, molecular manipulations, and gene regulatory network analysis to produce a systems-level model of how this Wnt signaling network governs anterior-posterior axis specification in the sea urchin embryo. Importantly, evidence from functional and expression studies in other embryos strongly suggests that aspects of this fundamental developmental mechanism are conserved in deuterostome embryos.

P3.160 RANGEL, R*; JOHNSON, D; California State University Long Beach; *racine.rangel@gmail.com*
Evaluating the effects of temperature on the metabolic rate of the Bluebanded Goby (Lythrypnus dalli)
As ocean temperatures steadily rise, marine species will be exposed to more extreme diel and seasonal fluctuations. These overall temperature increases may expose temperate reef species like the Bluebanded Goby (*Lythrypnus dalli*) to temperatures that are at or over their physiological optimum. Coping with temperatures above physiological optimum may have consequences that result in costly trade-offs between metabolism and processes such as growth and reproduction. However, basic metabolic rates of reef fishes with limited movement are relatively unknown. Using respirometry, we estimated basic oxygen consumption (V_f), mass-specific oxygen consumption (MO_2), and metabolic rate (MR) of *L.dalli* at three different temperatures (13˚C, 16˚C and 20˚C). To date, 28 replicate trials have been conducted and preliminary findings show significant increases of V_f, MO_2, and MR with temperature. Ongoing work is focused on refining the estimate of how quickly metabolism increases with temperature and any subsequent changes in energy allocation of temperate reef species.

16.4 RANKIN, JW*; BLASDELL, K; MCGOWAN, CP; University of Idaho; *jwrankin@uidaho.edu*
New Insights Into the Hill-type Muscle Model: A Comparison Between Simulated and Directly Measured Muscle Fiber Length Changes During Jumping in Kangaroo Rats
Few mammals rely on bipedal hopping as a primary locomotor behavior. Previous work using kangaroos and wallabies have found that, in these species, fast hopping is more economical than quadrupedal gaits, with improved economy likely linked to highly derived muscle-tendon unit (MTU) characteristics (e.g. short-fibered ankle extensors with long, slender tendons). On the other hand, small hoppers such as kangaroo rats have relatively thick ankle extensor tendons, which may reduce hopping economy. Instead, the thicker tendons suggest kangaroo rats may prioritize maximum jumping ability, a key evasive behavior. To investigate how MTU design influences possible trade-offs between hopping economy and jumping performance, a detailed musculoskeletal model of a desert kangaroo rat (*D. deserti*) hindlimb was created in SIMM from digitized surface scans and muscle dissections. As a first step, the model was used within an optimization framework to generate forward dynamics jumping simulations that reproduce collected kinematic and ground reaction force data. Predicted ankle extensor muscle excitation patterns were compared with experimental electromyogram (EMG) data. Simulated muscle length changes predicted by a Hill-type muscle model were then compared to *in vivo* fiber length data obtained via sonomicrometry. This presentation will discuss the similarities and differences between the *in vivo* and simulated muscle data, providing a perspective on the potential implications of and pitfalls in using simulations and traditional Hill-type muscle models when generating and testing inferences in comparative and paleontological biomechanical studies.

P1.224 RANKIN, AR*; TAYLOR, JRA; Scripps Institution of Oceanography, UC San Diego; *arankin@ucsd.edu*
The effects of reduced pH on decorator crab calcification and behavior
Crabs in the family Majoidae camouflage by decorating their exoskeletons with organisms and debris from their environment. This form of camouflage, involving both the act of decorating and carrying of these decorations, is thought to be energetically costly, and possibly even more so under stressful environmental conditions. Previous research has shown that many marine calcifiers experience stress and/or impacts on calcification under experimental ocean acidification conditions, which ultimately affects energy allocation. We therefore hypothesized that energy will be diverted towards regulatory processes, such as calcification, in decorator crabs under reduced pH conditions, thereby negatively affecting decorating behavior. Dwarf teardrop crabs, *Pelia tumida*, were exposed to ambient (8.1) and low (7.7) pH conditions for five weeks. Half of the animals in each treatment were given live *Halichondria panicea* sponge to decorate with, whereas the remaining animals were not allowed to decorate. Electron dispersive x-ray spectroscopy (EDX) showed that calcium and magnesium concentrations (wt%) of the exoskeleton did not change under reduced pH conditions. Neither mass nor percent coverage of sponge differed between decorated treatments, indicating no effect of reduced pH on decorating behavior. The ability of these decorator crabs to maintain normal calcification and decorating behavior under reduced pH conditions may aid in their camouflage and survival in the future oceans. This study adds to the growing number of marine species that appear to be resilient to ocean acidification.

P2.26 REDAK, C*; PECHENIK, J; PIRES, A; Kenyon College, Tufts University, Dickenson College; *redakc@kenyon.edu*
Effects of Larval and Juvenile Experience of Acidification on Shell Performance in a Gastropod
Dissolved CO_2 from natural and anthropogenic sources drives pH and other important parameters of carbonate chemistry in marine environments. Acidified conditions can inhibit growth of shells and skeletons in a variety of calcifying organisms. The caenogastropod *Crepidula fornicata* is a cosmopolitan intertidal and subtidal species that lives in environments subject to wide fluctuations in pCO_2 and pH. We have previously shown that larvae and juveniles grow at similar rates over the pH range of 7.6-8.0, but that larval experience of acidification can depress early post-metamorphic growth. In the present study we grew larvae to metamorphosis at ambient pH of 7.9-8.0, then cultured juveniles for 14 d at pH 7.6 or 8.0 and studied juvenile shell performance by measuring the force required to crush the shells. Mean values of crushing force did not significantly differ between shells of individuals reared at the two pH levels but were more variable within and between replicate cultures at the lower pH. Mean thickness also did not differ significantly between the two groups of shells. In order to investigate effects of larval and juvenile acidification experience on shell performance of younger juveniles, we reared another brood of larvae to metamorphosis at pH 7.6 or 8.0 and then cultured juveniles for 8 d at pH 7.6 or 8.0. Larval pH did not affect crushing force for juveniles reared at pH 8.0. Shells of juveniles reared at pH 7.6 were significantly weaker than those of their siblings that had been reared as juveniles at pH 8.0, even though they did not differ in average length. These results suggest that acidification may affect performance of early juvenile shells without affecting overall shell growth rates. Supported by NSF 1416690 and 1416846.

112.5 REEDY, A.M.*; SEEARS, H.A.; KAHRL, A.F.; GIORDANO, C.; WARNER, D.A.; COX, R.M.; University of Virginia, Auburn University; *amr3mb@virginia.edu*
Sexually antagonistic selection emerges in the adult life stage in a sexually dimorphic lizard
Sex differences in selection result in intralocus sexual conflict when the same alleles have opposite effects on fitness in males and females, and the resulting genomic tug-of-war can constrain the independent evolution of the sexes. Although the evolution of sexual dimorphism suggests that these constraints can be overcome, field studies provide multiple examples of sexually antagonistic selection persisting on highly dimorphic traits.Sexual dimorphism often develops gradually over ontogeny, yet studies of sexually antagonistic selection in the wild have rarely spanned multiple life stages, so it remains unclear whether and how sexual antagonism differs with life stage. To address this, we estimated sex-specific selection gradients for multiple sexually dimorphic traits across juvenile and adult stages in a closed island population of brown anole lizards (Anolis sagrei). We used exhaustive sampling via mark-recapture over a two-year period to track the survival of more than 5,000 lizards spanning three generations. Sex differences in survival rates were apparent at both juvenile and adult life stages, creating higher opportunity for selection in males. Selection for large body size was strong in juveniles of both sexes, and antagonistic selection was absent prior to the development of dimorphism. After the development of sexual dimorphism in adults, we found sexually antagonistic selection on body size and on the size of a sexually dimorphic ornament, the dewlap. Selection on body size reinforced sexual dimorphism by favoring large males and small females, whereas selection on the dewlap was opposite the direction of dimorphism, favoring smaller dewlaps in males. This latter result suggests a cost associated with an elaborate, sexually selected ornament.

P2.226 REEVE, R. E.*; NESTLER, J. R.; Washington State University, Pullman, Walla Walla University, Walla Walla; *robyn.reeve@wsu.edu*

Immune function in the sea cucumber Parastichopus californicus during visceral atrophy and regeneration

The sea cucumber *Parastichopus californicus* undergoes an annual cycle of visceral atrophy and regeneration. The trigger(s) of this process and evolutionary advantages are unknown. One hypothesis is that replacement of the gut may allow *P. californicus* to eliminate a dangerously high load of pathogenic bacteria, and permit repopulation by beneficial species. The ability to regenerate has been linked to the immune system in many species, including holothurians. However, the immune system of *P. californicus* has not been characterized during the cycle of visceral atrophy and regeneration. To better understand this species' immune system, we collected coelomic fluid samples from adult animals during the summer (all viscera present), fall (viscera degenerated), and winter (viscera regenerating) to examine coelomocyte and immunoenzyme concentrations. Additionally, during the summer and fall, adult *P. californicus* were injected with citrated sheep red blood cells to elicit an immune response. We found that the concentration of coelomocytes and immunoenzymes is lower in this species than in other holothurians. The general immune response of *P. californicus* differs depending on the season/visceral regeneration state. Specifically, this species' ability to respond to immune challenge in the fall appears to be stunted (lower coelomocyte concentrations for all subpopulations during this season) when compared to the response in summer. This immunosuppression could occur for two reasons. First, there is less energy available to put into the immune system because *P. californicus* has a reduction in metabolic rate when the viscera are atrophied. Second, coelomocytes make arise from the lumen of the respiratory trees and so this organ's degeneration during the fall could inhibit the creation of new immune cells.

68.4 REFSNIDER, JM*; CARTER, SE; CLIFTON, IT; SIEFKER, AD; STREBY, HM; VAZQUEZ, TK; Univ. of Toledo; *jeanine.refsnider@utoledo.edu*

Plasticity in Behavioral Thermoregulation by Lizards on an Elevational Gradient: A Reciprocal Transplant Experiment

Predicting how organisms will be affected by climate change is a complex challenge. Ectotherms, particularly lizards, are model systems for climate change impacts because their physiology and behavior are highly dependent on environmental temperatures. Lizards may be buffered from some effects of climate change due to their ability to behaviorally thermoregulate. It is generally assumed that behavioral thermoregulation is a phenotypically plastic trait, but determining whether between-population differences in thermoregulation are due to plasticity or local adaptation has been hampered by the difficulty of measuring thermoregulation in wild lizards in natural habitat, particularly when they are sheltered or otherwise difficult to observe. We used light-level data recorders to continuously record thermoregulatory behavior in cool, high-elevation and warm, low-elevation populations of desert short-horned lizards. We then reciprocally transplanted lizards and continued to record their thermoregulatory behavior when in a novel environment. In comparison to their thermoregulatory behavior at their home site, high-elevation lizards transplanted downslope spent more time buried in the substrate and less time basking in full sun, whereas low-elevation lizards transplanted upslope spent less time in shelters and more time basking in full sun. Our study demonstrates empirically that thermoregulation is a behaviorally plastic trait that can be adjusted immediately in response to novel environmental conditions. Further, we present a method for continuously recording thermoregulatory behavior in wild reptiles in their natural habitat.

P3.238 REGNAULT, S*; ALLEN, V; HUTCHINSON, JR; Structure and Motion Lab, Royal Veterinary College; *sregnault@rvc.ac.uk*

Modelling the Double Patellae of Ostriches (Struthio camelus), and their Effects on Muscle Moment Arms

The patella (kneecap) is a bone found within the tendon of the knee extensor muscle group. An often-cited and presumably important function of the patella is to increase the moment arm of the extensor muscle(s), and so reduce the force required from these muscles. This mechanical benefit may partly explain why evolution of the patella in birds seems to have coincided with greater knee flexion and a more crouched limb posture. The nature and magnitude of the patella's mechanical benefit(s) in birds is unclear, however. Ostriches diverge from the avian anatomical norm, with two patellar bones per knee rather than one, in a proximal-distal arrangement. The proximal patella is small and appears homologous to the single kneecap of most other birds, whereas the distal patella is elongate, closely attached to the tibia, and reminiscent of the extended tibial crest (a retroarticular process) seen in some birds. Does this specialized morphology correlate with alterations in the mechanical function(s) of the knee joint sesamoids and their associated muscles? Here we modify a previously published ostrich musculoskeletal model, adding patellae and kinematics obtained from biplanar fluoroscopy (XROMM) of an adult cadaver, to explore the mechanics (particularly moment arm ratios) of these sesamoids. We find that the distal patella is functionally more similar to a sesamoid than a retroarticular process, rotating to remain pressed against the femur as the knee bends. Both patellae appear to provide a low mechanical advantage throughout knee extension, though this gearing effect increases as the knee joint extends.

S9.12 REHAN, SM; University of New Hampshire; *sandra.rehan@unh.edu*

Social aggression, experience, and brain gene expression in a subsocial bee

Understanding the genetic mechanisms behind aggressive behaviors can yield insight into the formation of dominance hierarchies, and thus social systems in general. Studies in a range of taxa and levels of social complexity have identified numerous candidate genes for aggression. At the center of these studies is research into the effects of social experience and agonistic contest outcomes. Data has shown significant changes in brain gene expression resulting from repeated winning and losing, as well as changing dominance rank, primarily in obligately social species. However, our knowledge of the genetic underpinnings of behavior in subsocial organisms is relatively poor. Because subsociality represents the simplest form of social living, understanding the behavioral genetics of this level of sociality provides the basis for understanding all other forms of social living. Here we measured the effects of aggression and social experience on gene expression in the brain of a subsocial bee, *Ceratina calcarata*. We compared expression profiles of individuals that had experienced repeated winning, repeated losing, or a change in rank during repeated encounters. We found that consistent winning accounted for the majority of variation in brain gene expression, followed by changing rank over maintaining rank. Comparing the resulting differentially expressed genes and corresponding gene ontologies to those of a diversity of invertebrate and vertebrate taxa, we find similarly upregulated and enriched terms for memory/learning, axonogenesis, and transcription regulation. Significantly over-represented cis-regulatory elements potentially responsible for differential regulation of genes related to aggressive/dominant behavior are identified. We present evidence for both genetic and cis-regulatory mechanisms for aggression of broad interest to the study of social evolution.

P1.268 REHM, JC*; CHENEY, JA; BREUER, KS; SWARTZ, SM; Brown University, Providence, Brown University, Providence and Royal Veterinary College, London; *jeremy_rehm@brown.edu*

The Function of Wing Membrane Muscles in Bats

The plagiopatagiales proprii are an array of muscles hypothesized to modulate movement of the armwing membrane and prevent excessive billowing during flight in bats. EMG recording demonstrates these muscles activate during the downstroke, but their mechanical role remains uncertain. To improve our understanding of their function, we recorded high-speed videos of three bats flying in a wind tunnel before and after nanoliter injections of diluted botulinum toxin A (or Botox®) into the plagiopatagiales proprii, causing temporary muscle paralysis without loss of sensation. Surprisingly, bats were only capable of sustained flight in the presence of a headwind after injection. Measurements of membrane motion and camber were made from 3D time-resolved point cloud reconstructions. Following loss of muscle function, kinematic parameters such as flapping amplitude and frequency changed modestly, but abduction of the fifth digit decreased substantially; this contrasted with our expectation that bats would increase extension at wing joints to maintain membrane tension. At comparable flight speeds, the temporal fluctuation in the membrane deformation, as monitored at a representative point in the mid-armwing, increased after injections, particularly during the first third of downstroke. In addition, the variance in the spanwise camber of the wing increased and qualitatively resembles the control case at low flight speed. The functional implications of these measurements and their relation to the loss of plagiopatagiales activity remains to be examined in more quantitative detail.

88.4 REHOREK, SJ*; HILLENIUS, WJ; THEWISSEN, JGM; Slippery Rock University, Slippery Rock, College of Charleston, Charleston, NEOMED, Rootstown; *susan.rehorek@sru.edu*

Comparative anatomy of the nasolacrimal apparatus: the case of a dolphin (Stenella attenuata).

The nasolacrimal duct (NLD) connects the orbital and nasal regions in many tetrapods. Caudally, this duct opens into the anterior/ medial orbital region, in close association with the nictitating membrane or an anterior orbital gland (e.g., Harderian gland: HG). The HG and NLD develop in close association with each other in several tetrapod vertebrates. In cetaceans, there is no NLD in the adult and the identity of the orbital glands is described differently by different authors, possibly reflecting taxonomic variation. Through examination of an embryological series of the pantropical spotted dolphin (*Stenella attenuata*) numerous divergences from other tetrapods were observed. Underdeveloped eyelids and a few ventral orbital glands were present by late Carnegie stage 17/18. By Carnegie stage 19, conjunctival glands encircled the eyeball. In fetal stage 20, these conjunctival glands proliferated, eyelids (and associated palpebral glands) formed, and a duct similar to the NLD appeared. There was subsequent reduction of palpebral glands and the NLD by fetal stage 21/22. There was regional growth of the conjunctival glands during these fetal stages. In contrast to other tetrapods, in which there are distinct zones of orbital gland development and the NLD connects the orbit to the nasal region before the lacrimal bone appears. This conjunctival ring of glands was described in some adult cetaceans and it was proposed to produce a protective oily sheet for the cornea. The development of both the NLD and orbital glands may be other examples of developmental drift. The fossil record shows that the NLD was present in the earliest, amphibious, freshwater cetaceans but was lost early on as they invaded the oceans.

MOORE.1 REID, Rosalind; Council for the Advancement of Science Writing; *rosreid@gmail.com*

Only Converse? A Journalist Sizes Up the Problem of Science Communication

The rise of active learning in science education has an analog in the world of science communication. The notion of a passive audience has been destroyed by the surging popularity of social media. Today's audience talks back; in fact, the voices and choices of active reader-commentators commonly drown out the voice of the sage. This online world may seem a largely hostile one to scientists, but three decades of experience helping scientists communicate gives Rosalind Reid reason for optimism. She will share some recipes for successful science communication, identify novel opportunities that exist in the new environment, and explain how "science as a way of knowing" might be an especially powerful starting point—assuming scientists are willing to think about new ways not just to communicate but to do science.

32.5 REILLY, SM; MONTUELLE, SJ; SCHMIDT, A; KRAUSE, C; NAYLOR, E; JORGENSEN, ME; ESSNER, RL*; Ohio University, Athens, Ohio University, Athens and Klinik Bavaria Kreischa, Germany, Ohio University, Athens, and University of California, Riverside, University of Missouri, Columbia, Southern Illinois University Edwardsville; *ressner@siue.edu*

Pelvic Function in Anuran Jumping: Interspecific Differences in the Kinematics and Motor Control of the Iliosacral Articulation During Take-off and Landing

We compared iliosacral movements and motor patterns during jumping and landing in anurans with "lateral-bender" and "rod-like" pelvic designs. Muscle activity patterns, iliosacral anteroposterior (AP) movements and sagittal bending of the pelvis were quantified in the lateral bending *Ascaphus* (Leiopelmatidae) and *Rhinella* (Bufonidae) and the rod-like *Lithobates* (Ranidae). All species exhibited sagittal extension during take-off; however, trunk elevation occurred significantly earlier in the rod-like pelvis. *Piriformis* muscles depressed the urostyle whereas *longissimus dorsi* muscles elevated the trunk during take-off. *Coccygeoiliacus* muscles produced anterior translation of the sacrum on the ilia. A new model illustrates how AP translation facilitates trunk extension in lateral-benders thought to have limited sagittal bending. During landing, AP translation patterns are similar, as impact forces slide the sacrum from its posterior to anterior limits. Sagittal flexion during landing differs among taxa and AP translation during landing may dampen impact forces, especially in *Rhinella* in which pelvic function is tuned to forelimb-landing dynamics. The flexibility of the lateral-bender pelvis helps to explain retention of this basal configuration in many anurans. The novel function of the rod-like pelvis may be to increase the rate of trunk elevation relative to faster rates of energy release from the hind limbs, enabling them to jump farther.

52.1 REN, Z*; DI SANTO, V; HU, K; YUAN, T; LAUDER, GV; WEN, L; Beihang University, Harvard University; *liwen@buaa.edu.cn*

Understanding Fish Linear Acceleration Using an Undulatory Bio-robotic Model with Soft Fluidic Elastomer Actuated Median Fins

Fish commonly execute rapid linear accelerations initated during steady swimming, and yet linear accelerations are one of the least understood aspects of aquatic propulsion. In this study, we used synchronized ventral and lateral high-speed cameras to examine the linear acceleration of the largemouth bass (Micropterus salmoides). Bass were studied during accelerations from -3.16 to 3.82BL/s2 starting from different steady swimming speeds (1 and 2 BL/s). We observed that the soft-rayed dorsal/anal fins dynamically erect and fold down to change the fin area by more than 70%, and flap side to side within each movement cycle. To better understand the hydrodynamic functions of fin motions during linear acceleration, we implemented a biomimetic undulatory fish robotic model with median fins that include a spine-rayed dorsal fin, soft-rayed dorsal/anal fins, and a caudal fin, which were manufactured using multi-material 3D printing. We used an array of fluidic elastomeric soft actuators to mimic the dorsal/anal inclinator and erector/depressor muscles, which allow the soft fins to erect and fold down and flap laterally. The robotic fish was then mounted to a servo-actuated towing system with programmed speeds that have similar profiles to that of live fish during linear accelerations. A multi-axis force transducer was used to measure three forces and three torques on the robotic model, and DPIV measurements were conducted simultaneously to calculate wake flows. This bio-robotic model could be a promising approach for studying the dynamics of fish swimming behaviors, including linear acceleration, steady swimming, and burst and coast.

135.5 RENDLEMAN, AJ*; RODRIGUEZ, JA; OHANIAN, A; CHANG, B; PACE, DA; California State University, Long Beach; *anniejeanrendleman@gmail.com*

Comparing the Developmental Physiology of Two Morphologically Distinct Sea Urchin Larvae: Strongylocentrotus purpuratus and Centrostephanus coronatus

Planktotrophic larvae typically possess appendages circumscribed with cilia, which aid in algal food capture. Therefore, larval morphology can significantly affect feeding ability and growth during early life history stages of many marine species. The majority of sea urchin larvae (echinoplutei) develop eight ciliated arms, as seen in the purple urchin *Strongylocentrotus purpuratus*. The crowned urchin *Centrostephanus coronatus*, however, exhibits a derived "echinopluteus transversus" with only two relatively large arms. Little is known about the energetics of growth in echinoplutei, let alone in transversus forms. This study seeks to understand how the functional morphology of each larval form may result in different physiological constraints and abilities. Despite the distinct morphologies of each larval form, total ciliary band lengths did not differ between the two species. However, *S. purpuratus* exhibited notably greater ingestion rates than *C. coronatus* (236 vs. 117 cells hr^{-1}). Larvae of *S. purpuratus* grew more protein (4,103 vs. 670 ng) and used 8-times more energy for metabolism (89 vs. 11 mJ) than *C. coronatus* after 25 days. *Strongylocentrotus purpuratus* also had a significantly higher assimilation efficiency (64% vs. 26%). These data show that the typical echinopluteus of *S. purpuratus* exhibits a high physiological growth capacity for relatively rapid larval development. The decreased energy of development observed in the *C. coronatus* transversus form may be advantageous for an extended planktonic duration and long-distance dispersal potential.

115.1 RENSEL, MA*; DING, J; SCHLINGER, BA; Univ. of California, Los Angeles; *mrensel@ucla.edu*

The (Non) Stressed Brain: Local Metabolism Regulates Corticosterone Action in the Songbird CNS

Glucocorticoids (GCs) perform diverse regulatory actions in the body under baseline conditions and during stress. In the brain, GCs participate in negative feedback regulation of the hypothalamic-pituitary-adrenal axis and influence cognition, at times enhancing or inhibiting cognitive capabilities. Critically, excess GCs inhibit neurogenesis, which is widespread in the songbird brain and functionally significant for behavior. Using in vivo microdialysis, we showed that the male zebra finch brain contains detectable, fluctuating, and region-specific levels of GCs. However, while robustly elevated in the periphery, GCs did not significantly increase in the brain during and after an acute stressor. In zebra finches, regional differences in GCs correspond to expression levels of 11β hydroxysteroid dehydrogenase type 2 (11β HSD2), an enzyme that de-activates GCs, leading us to hypothesize that 11β HSD2 regulates neural GC levels. We tested this hypothesis in males and females by retrodialyzing the 11β HSD2 inhibitor carbenoxolone (CBX) during microdialysis, followed by a standard stress series. We also examined the co-expression of the GC receptors MR and GR, along with 11β HSD2, in several regions of the brain including the hippocampus and caudal medial nidopallium (NCM). These regions lie adjacent to the ventricular zone where neurogenesis occurs. The results of these experiments are expanding our understanding of the mechanisms by which the brain regulates exposure to GCs, a topic of critical importance for predicting the impact of stress on reproduction, learning, and memory, especially in the popular songbird model system.

27.7 RESH, CA*; MAHON, AR; Central Michigan University; *carlee.resh@gmail.com*

Genomic analyses of invasive grass carp (Ctenopharyngodon idella) in Lake Erie

Invasive grass carp (*Ctenopharyngodon idella*) were introduced into the United States in the early 1960s to help control nuisance aquatic vegetation in ponds and lakes. Since their introduction, they have escaped or been released into multiple water bodies with the overall extent of their impact not fully known. Grass carp pose a significant risk to native species through their ability to destroy food sources, shelter, and spawning areas for native species. Although these carp are routinely bred as triploid (reproductively sterile) and are still distributed in certain regions around the Laurentian Great Lakes, a growing number of potentially reproductively capable (diploid) individuals have been recently captured in Lake Erie. The distribution and population size of these fish in the wild remains unknown. In this study, we assess the reproductively viable grass carp captured in Lake Erie over the last two years. By analyzing the genomes of captured diploid fish for single nucleotide polymorphisms (SNPs) detected through 2b-RAD sequencing methods, we calculate both population structure and effective population size of this harmful invasive species. These results will enable management to better understand the extent of the current grass carp invasion and assist in the management of existing populations.

P2.250 RESNER, EJ*; BELANGER, BG; HARDY, KM; California Polytechnic State University; *eresner@calpoly.edu*
Effect of Oxygen Limiting Tidal Conditions on Hemolymph Parameters in the Giant Acorn Barnacle, Balanus nubilus.
The giant acorn barnacle, *Balanus nubilus*, is a low-intertidal organism that has achieved scientific notoriety owing to its extraordinary muscle fiber dimensions (diameters can exceed 3mm in adults!). At these sizes, metabolically active muscle cells are at risk for insufficient oxygen delivery owing to low SA:V ratios. In addition to the fiber size limitations, *B. nubilus* likely experience periodic hypoxia during low-tide emersion and lack an oxygen binding pigment (e.g., hemocyanin). This combination of oxygen-depriving features poses a triple-threat to muscle function. As such, we are interested in the unique metabolic and structural adaptations of giant *B. nubilus* muscle fibers that allow them to maintain function in spite of the internal oxygen environment. The first step in this investigation is to describe the changes in hemolymph gas and electrolyte levels that occur during bouts of aerial emersion. To this end, we measured hemolymph pO_2, pCO_2, pH and [K+] at 0, 3, 6 and 9h following exposure to air emersion, anoxic immersion, and normoxic immersion. We found that hemolymph pO_2 was significantly decreased in the anoxic barnacles by 3h, though both anoxic and air emersion were significantly lower than normoxic barnacles by 9h. We also revealed a significant increase in pCO_2 by 6h in the anoxic group, and by 9h in both anoxia and emersion. Thus, tidal emersion only mildly decreases hemolymph pO_2 and increases pCO_2 compared to the more extreme stress of submerged anoxia. Given the unusually high capacity for aerial oxygen uptake seen in other barnacles, these data were not altogether surprising. What was unexpected, however, was a significant increase in [K+] that occurred by 6h in both the emersion and anoxic groups. The reason for this change is yet to be determined.

P2.127 RESTREPO, LF*; RICE, MA; OPHIR, AG; Cornell University; *lfr38@cornell.edu*
Mechanisms of Monogamy: Modeling dynamics of paternity and promiscuity in prairie voles (Microtus ochrogaster)
The prairie vole (*Microtus ochrogaster*) is a socially monogamous rodent, in which individuals form long-term pairbonds that are characterized by exclusive home ranges. Males monopolize one female, guarding her to secure intra-pair fertilizations (IPFs) and ensure paternity. However, males are opportunistic and seek additional matings with females, leaving their partner unguarded. Based on semi-natural field studies, some have suggested that the success associated with a male's decision to seek more mates over guarding his partner is impacted by the amount of other males leaving their nests to seek extra-pair fertilizations (EPFs). The amount of EPF-seeking males impacts both the likelihood of encountering an unguarded paired female and of being cuckolded (losing IPFs). It remains unclear under which conditions it is optimal to stay and guard or seek EPFs. Using field data to generate parameters, we used optimal performance modeling to ask when is it most reproductively advantageous for a male to seek EPFs despite the risk of losing IPFs. We found that at high levels of EPF-seeking in the population, the rate of EPFs for a subject begins to slowly outpace the rate of cuckolding. This result suggests that mate searching becomes the optimal tactic for the subject once the population of EPF-seeking males reaches approximately 60%. We also found that the ratio of EPFs to IPFs for the subject dramatically changes as EPF-seeking percentages in the population increase, though total fertilizations remain constant. Our results show the dynamic nature of reproductive decision-making in the prairie vole model, and demonstrate that alternative reproductive decisions yield subtle differences despite appearing as balanced strategies.

48.3 REVZEN, S; U Michigan, Ann Arbor; *shrevzen@umich.edu*
When do locomotor appendages get complicated?
Some animals contact the substrate on which they move using simple appendages -- limbs with few degrees of freedom, which interact with the substrate with what is effectively a single rigid contact, such as a horse's hoof. Other animals have large multi-fingered feet, prehensile tails, or multi-segment tarsi. Why do some locomotor appendages have many mechanical degrees of freedom while others have only a few?

From first principles of Newtonian mechanics, it can be seen that when animals need to produce distinct and unanticipated mechanical configurations ("symbols") so rapidly that environmental noise becomes a challenge, this produces a lower bound on the number of degrees of freedom needed in the body.

In particular, if an animal needs to emit N different symbols, the animal's energy budget for emitting each symbol must be at least order of 2N times the energy of typical environmental noise -- otherwise simple bodies cannot work. As this safety margin approaches 1, the number of degrees of freedom needed in the locomotor appendages quickly rises to infinity.

P3.219 REYNAGA, CM*; EATON, C; AZIZI, E; University of California, Irvine; *cmmreynaga@gmail.com*
Effects of substrate compliance on hindlimb kinematics of jumping Cuban tree frogs (Osteopilus septentrionalis)
Arboreal frogs navigate complex environments and face various changes in the mechanical properties of the physical environment. These changes in substrate compliance and elasticity can impose challenges when jumping off structures like leaves or small branches. An optimal well-coordinated jump might allow for the recovery of elastic energy stored in the substrate and potentially amplify mechanical power by effectively adding an in series spring to the hindlimbs. However, in a poorly coordinated jump the energy applied to the substrate is not recovered. We aim to understand whether jumping organisms modulate their hindlimb kinematics to maximize energy recovery from an elastic substrate. We have designed a software-controlled jumping platform equipped with a real-time feedback controller that allows us to modulate the properties of the substrate. We quantify the kinetics and kinematics of Cuban tree frogs jumping off platforms with varying mechanical properties. We find that animals can recover some of the energy stored in the substrate but do so with little kinematic modulation when faced with substrates of varying properties. This result highlights a potential trade-off between jumping performance (e.g. power, acceleration) and responsiveness in animals that rely on elastic mechanisms to amplify power. This work will serve to broaden our understanding of how animals sense and respond to complex environments with varied mechanical properties.

P2.237 REYNOLDS KIRBY, A.*; NELSON, D.; HEUER, R.; MAGER, E.; STIEGLITZ, J.; GROSELL, M.; BENETTI, D.; CROSSLEY II, D.A.; University of North Texas, Denton, University of North Texas, Denton; University of Miami, Florida, University of Miami, Florida; *amandareynolds@my.unt.edu*

Changes in Cardiac Mitochondrial Bioenergetics after 24h of Crude Oil Exposure in Sub-adult Mahi-mahi (Coryphaena hippurus)

Polycyclic aromatic hydrocarbons (PAHs) in crude oil have been shown to impair cardiac function. Since mitochondrial function is critical to support aerobic metabolism through the production of ATP, abnormal mitochondrial bioenergetics could be the basis for the impaired cardiac function associated with crude oil exposure. We hypothesized that cardiac mitochondrial function would be reduced after 24h of crude oil exposure. Sub-adult (0.95 ± 0.11 kg, n = 16) Mahi-mahi *(Coryphaena hippurus)* were kept in 300L static tanks of 35 ppt seawater at 26 °C for 24h in control conditions or 10% crude oil solution. Permeabilized cardiac muscle fibers were isolated from ventricle tissue for study. A portion of the tissue was flash frozen and used in mitochondrial density and enzyme activity analyses. No statistical differences were observed in mitochondrial respiration rate or respiratory flux control ratios. This suggests that 24h of oil exposure has no impact on the electron transport system. In addition, no changes were observed in mitochondrial density, enzymatic activity, or Vmax between treatments. However, oil-exposed mahi had reduced $\dot{V}O_2$ at lower ADP concentrations and the apparent $K_{m\,ADP}$ was 3-fold higher in oil-exposed mahi. The greater need for ADP in oil-exposed mahi was not explained by changes in respiration rate, mitochondrial density, or enzyme activity. We speculate that the increased need for ADP is potentially due to a weakening mitochondrial membrane or allocation to cellular processes.

P1.95 RICE, D.*; WILSON, K.A.; University of Cincinnati, University of Cincinnati Blue Ash College; *keen.wilson@uc.edu*

Analysis of the 5' regulatory region of the goosecoid gene between sea urchins with widely divergent early developmental modes

In addition to a high degree of conservation in the use of major effect genes in a variety of organismal body plans, it is apparent that such genes can also be involved in major evolutionary transformations in developmental programs. Previous studies revealed that *goosecoid (gsc)*, a highly conserved and developmentally important gene, was involved in mediating the evolution of direct developing larvae within the genus *Heliocidaris*. This involvement was not due to a simple presence or absence of expression, but in the details of the gene's regulation. Using this information as a starting point, we ask two questions about development: 1) can we identify possible proximal control region sequences in *gsc* important to developmental mode between *H. tuberculata*, *H. erythrogramma* and the model indirect developing sea urchin *Strongylocentrotus purpuratus* and 2) are identifiable changes to *gsc* necessary for the evolution of direct development in sea urchins generally? As most common methods of promoter analysis are not available within the echinoderms, we initiated a study into the proximal upstream promoter region of *gsc* through the use of TAIL-PCR. Sequence has been obtained from *H. tuberculata*, *H. erythrogramma* and *Holopneustes purpurascens*, an urchin with independently derived direct development sharing a common ancestor with the genus *Heliocidaris* in the lower cretaceous. These sequences are compared to one another and to that of *Strongylocentrotus purpuratus*, and a search for probable transcription factor binding sites using web based tools is performed to identify similarities and differences correlated with developmental mode. Implications for the evolution of developmental mode as well as future directions for the study are discussed.

144.5 RICE, MA*; SANIN, G; OPHIR, AG; Cornell University, Georgia State University; *mr868@cornell.edu*

Effects of operational sex ratio on spatial memory, reproductive success, and neural phenotype in prairie voles (Microtus ochrogaster)

Intensity of sexual selection is shaped by the operational sex ratio (OSR), which is the relative ratio of males to females ready to mate. At a proximate level, male biased OSR increases inter-male competition and variation in reproductive success. Spatial memory is a crucial mechanism for mating success, as individuals must locate potential mates in space and time. Intensity of sexual selection (at the population level) is potentially an important factor in shaping spatial memory, particularly in a mating context. Therefore manipulating the OSR context should reveal the importance of spatial memory in a population. For example, if male-male competition is high, males may benefit by knowing who and where their competitors are. Hence intra-sexual selection should influence spatial memory. We predict that individual variation in mechanisms controlling reproductive decisions and spatial memory may predispose some animals to thrive in one OSR context over another. We compare differences in reproductive success and performance in a spatial memory test for male prairie voles (*Microtus ochrogaster*) freely living in outdoor enclosures under male- and female-biased OSRs. Males in the male biased (MB) context performed better at the spatial memory test than those from the female biased (FB) context. We found that within each OSR context, reproductive success and spatial memory performance appear to be correlated. Neural phenotype for oxytocin receptors (a mechanism that modulates spatial memory and mating) tended to differ between contexts. Our results indicate that mechanisms associated with spatial memory are susceptible to selective pressures resulting from changes in OSR and could have immediate consequences on reproductive success.

P3.251 RICH, M; DONATELLI, C*; SUMMERS, A; GIBB, A; Cornell University, Tufts University, Friday Harbor Labs, University of Washington, Northern Arizona University; *mir42@cornell.edu*

Amp it up: Morphological and kinematic scaling in the Penpoint Gunnel (Apodichthys flavidus)

Fish grow in mass and length across orders of magnitude as they transition from the juvenile to adult stage. As they grow, the way they interact with the environment may change. In this study, we looked at scaling relationships in an elongate swimmer, Apodichthys flavidus (the penpoint gunnel) from small juveniles to large adults, across two orders of magnitude in mass. We recorded videos of fish swimming steadily around a track and used custom Matlab software to extract kinematic parameters such as tail beat frequency, amplitude, stride length, and velocity and determined their scaling relationships relative to mass. Our null model was based on A.V. Hill's assumptions of geometric similarity, which predicts that frequency should decrease in direct proportion with a increase in stride length, resulting in a constant swimming velocity. For penpoint gunnels, overall body shape scaled isometrically in accordance with the null model. The only swimming parameter that differed significantly from the null model was velocity, which increased with mass with a scaling coefficient of 0.14, instead of the null model's prediction that all fish will swim at the same velocity (mass scaling exponent, m = 0). Thus, fish increase their swimming velocity as they grow, but swimming velocity does not scale in direct proportion with body length. Reynolds numbers calculated for segments at the head and tail of small, medium, and large individuals suggest that small fish exist either wholly in the intermediate Reynolds number regime, or with their heads in the intermediate regime and their tails in the inertial regime. Despite a predicted change in Re, the persistence of isometric scaling in morphology and kinetics suggests that changes in fluid regime do not appear to dictate swimming movements in elongate fish as they grow.

P3.141 RICH, M; THOMPSON, CM*; POPESCU, VD; Ohio University; *ct824310@ohio.edu*

Using multi-species modeling to understand the terrestrial carnivore community composition and distribution in Southeastern Ohio

Understanding community composition and distribution of species is vital for implementing sound management and conservation techniques. In particular, carnivores play vital roles in maintaining ecosystem integrity as top-down trophic pyramid regulators. Without the appropriate balance of predators, populations at lower trophic levels often explode and shortly crash, making the system unstable and conservation problematic. Many regions in the US are witnessing a comeback of terrestrial carnivores after >100 years of absence, yet the trophic relations in these ecosystems have not been quantified. To address this problem, we investigated the carnivore community composition in southeast Ohio, a forested area where species such as black bears, bobcats, and fishers are currently expanding their ranges, using baited camera traps. We monitored 48 trail cameras for approximately 3,0000 trap nights between May and July 2016 within 300 km2. Using an occupancy modeling framework we investigated local and landscape predictors of occurrence for red and gray foxes (*Vulpes vulpes*, *Procyon cinereoargenteus*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), as well as minks (*Mustela vision*) and long-tailed weasels (*Mustela frenata*). Using a multi-species approach, we determined patterns of species co-occurrence and concluded that interference competition shaped mesocarnviore relations. Our results shed light on the carnivore community composition in SE Ohio and provide critical information for state and federal wildlife management agencies.

128.4 RICHARDS, CT*; PORRO, LB; COLLINGS, AJ; Royal Veterinary College; *ctrichards@rvc.ac.uk*

The Dynamics of Trajectory Control in Jumping Frogs

The kinematic flexibility of frog hindlimbs enables multiple locomotor modes within a single species. Prior work has extensively explored maximum performance capacity in frogs; however, the mechanisms modulating performance within locomotor modes remain unclear. We measured how *Kassina maculata* modulates jump trajectory from horizontal to nearly vertical. Specifically, how do 3D motions of leg segments coordinate to move the center of mass (COM) upwards and forwards? How do joint rotations modulate jump angle? High-speed video was used to quantify 3D joint angles and their respective rotation axis vectors. Inverse kinematics was used to determine how hip, knee and ankle rotations contribute to components of COM motion. We found two possible mechanisms for increasing takeoff angle: Firstly, greater knee and ankle excursion increased shank adduction, elevating the COM. Secondly, during the steepest jumps the body rotated rapidly backwards to redirect the COM velocity. This rotation was not caused by pelvic angle extension, but rather by kinematic transmission from leg segments via reorientation of the joint rotation axes. We propose that *K. maculata* uses proximal leg retraction as the principal kinematic drive while dynamically tuning jump trajectory by knee and ankle joint modulation. We will further explore direct causes for joint-level control using forward dynamic musculoskeletal modelling.

122.6 RICHTER, MM*; BARNES, BM; O'REILLY, KM; FENN, AM; BUCK, CL; Western Kentucky Univ., Univ. of Alaska, Fairbanks, Univ. of Alaska, Fairbanks, Institute of Arctic Biology, University of Portland, Harvard Medical School, Northern Arizona Univ.; *melanie.richter@wku.edu*

The influence of androgens on hibernation phenology of free-living arctic ground squirrels

Many free-living ground squirrel species are sexually dimorphic in hibernation phenology. The underlying causes of these differences are unknown. Androgens, testosterone (T) in particular, inhibit hibernation. To determine the influence of endogenous androgens on annual timing of hibernation and aggression, we measured circulating levels of T and dehydroepiandrosterone (DHEA), an adrenal androgen implicated in non-mating season aggression in other species, in free-living male arctic ground squirrels (*Urocitellus parryii*, AGS). We also manipulated endogenous androgen levels by surgical castration, and consequently compared body temperature records from intact (n=24) and castrated (n=9) males to elucidate the influence of endogenous androgens on annual body temperature rhythms. Unsurprisingly, the highest T levels (0.69±0.20 ng/mL) were found among reproductively mature male AGS in spring, whereas, both immature males in spring and all males in late summer had T levels an order of magnitude lower (0.06±0.00 and 0.07±0.01 ng/mL, respectively). DHEA levels were higher in males during the late summer compared to reproductively mature males in spring (124.6±20.8 and 40.6±4.2 pg/mL, respectively). Eliminating gonadal androgens via castration resulted in males remaining heterothermic significantly later in spring (Julian date 112.1 ± 2.9) than reproductive males (87.1±3.9) but did not change the timing of hibernation onset (castrate: 284.8±1.0 vs. intact: 276.2±3.1). We conclude that while androgens play a significant role in spring hibernation phenology of males, their role in fall hibernation onset is unclear.

P2.96 RICHTER, MM*; ASHLEY, NT; COOPER, LN; Western Kentucky University; *melanie.richter@wku.edu*

A polar day's-worth of stress - circadian variation of adrenocortical responses to stress in arctic-breeding passerine birds

During summer in the high Arctic (71.29°N, 156.79°W) the sun does not set for >2 months. Therefore, migratory, arctic-breeding birds experience 24h of constant light during their breeding season. Among those migrants are two sympatric species that, while in the same family and can interbreed, differ in life-history traits. Lapland longspurs (*Lapponicus calcarius*) are monogamous and nest on the open tundra whereas snow buntings (*Plectrophenax nivalis*) nest in cavities and engage in extra-pair matings. Both species retain diurnal activity patterns during the polar day, and become quiescent between 00:00 and 04:00. To determine whether there is a circadian rhythm in the adrenocortical response to stress, free-living birds of both species were captured during the nesting stage and held at the following time points to collect blood samples: baseline (<2min post-trap), 10min post-trap and 30 min post-trap. Plasma was then assayed for corticosterone concentration using ELISA. For both species, no discernible circadian rhythms were detected in baseline corticosterone levels. However, snow buntings displayed a trend for increased stress-induced corticosterone (30min) as the polar day progressed (Circwave harmonic regression, $p = 0.089$). While preliminary, this study suggests that a lack of circadian variation in ground-nesting Lapland longspurs may represent an adaptation to round-the-clock predation pressures experienced at their nests.

P2.201 RICHTER, C*; DIGIULIO, S; LEONARD, J; Northern Michigan University; *crichter@nmu.edu*

A Herpetological Survey of Virgin Islands National Park, St. John, USVI

Reptile and amphibian species around the globe are under threat from climate change, habitat destruction, and exploitation; many species are at risk of extinction. Islands, including those in the Caribbean, are especially vulnerable due to their dynamic nature and endemism. From February 27, 2016 to March 5, 2016, we conducted a survey of Virgin Islands National Park on St. John, USVI to evaluate the species present on the island, as well as their distribution and density. Using visual encounter and vocalization surveys, and opportunistic encounters, we surveyed for reptiles and amphibians across different regions within the park. We used a USGS survey conducted by Rice and coworkers (2001) as a reference and also provided accounts of species not seen during the previous survey. We found 13 of the 17 previously reported species on the island including the blind snake *Typhlops richardi*, worm lizard *Amphisbaena fenestrata* and the red footed tortoise *Geochelone carbonaria*; species not observed during the previous survey. Our survey allowed us to track changes in species distribution and the status of non-native herpetofauna and their spread across the island. Most non-native species are still confined to the disturbed areas, while native species maintain their distribution across specific habitat gradients. Our results suggest that while the herpetofauna is undergoing changes due to invasive species and climate change, the overall community is relatively stable. Our survey provides useful information to the National Park Service regarding habitats used by several reclusive taxa and may be important as climate change alters local habitat conditions.

38.7 RIDDELL, EA*; CARLO, MA; APANOVITCH, EK; SEARS, MW; Clemson University; *eriddel@clemson.edu*

Potential responses to climate change are improved by physiological acclimation of water loss

Climate change threatens to increase extinction rates due to rapidly warming global temperatures. Species distribution models (SDMs) are critical to predicting the potential threat of a warming world by estimating an organism's capacity to remain active in their habitat given their physiological requirements and local climatic conditions. However, SDMs often ignore the capacity of animals to acclimate by reversibly adjusting physiological traits in response climatic conditions. By being susceptible to rapid dehydration, amphibians might increase skin resistance to water loss (r_i) in order to maximize the amount of time available for activity. We tested the capacity of an abundant terrestrial salamander (*Plethodon metcalfi*) to acclimate r_i in response to natural changes in climatic conditions that occur with elevation and seasons. We measured r_i of salamanders using a flow-through system capable of precise control over temperature and humidity. The results demonstrate that salamanders consistently increase r_i in response to warm temperatures and high VPDs. We then used a mechanistic SDM to understand how acclimation of r_i can influence activity time. Under a warming climate, the SDM predicts that average nightly activity time will be reduced by 60% by 2100 without acclimation. However, incorporating acclimation of r_i increases average nightly activity time by 26% relative to predictions without acclimation. These results underscore the potential for acclimation of physiological traits to improve predictions on the effects of climate change by incorporating important biological processes.

141.1 RIDDLE, MR*; TABIN, CJ; Harvard Medical School, Boston; *mriddle@genetics.med.harvard.edu*

The Eyeless Mexican Cavefish Astyanax mexicanus as a Model to Investigate Development and Evolution of the Gastrointestinal (GI) Tract

Animals flourish in nearly every environment on Earth as they have evolved numerous mechanisms to efficiently assimilate and use energy. How the GI tract evolves in response to change is not well understood although dramatic variation in structure and function is apparent across species. We are investigating GI evolution in a single species in the process of diversifying: the teleost fish *Astyanax mexicanus*. This fish exists as a river-dwelling form with abundant food, and multiple independently derived cave-dwelling forms that are entirely reliant on external food sources brought in by flooding. Although separated for millions of years, the river and all cave forms are interfertile allowing us to investigate the genetic basis of evolution in a low-nutrient environment. Cavefish have increased appetite and fat storage, and can survive long periods of starvation. We examined the GI tract of fish from the river and the Tinaja cave and found that cavefish have a longer and wider GI tract that, unlike the GI tract of the river fish, does not shrink dramatically during starvation. These differences may represent altered intestinal stem cell dynamics. The cavefish GI tract is also morphologically distinct; Tinaja have 6 finger-like projections posterior to the stomach (pyloric caeca), while river have 7 to 10 caeca. These mysterious structures vary from 1 to 1,000 in fish species. Caeca number is a multigenic trait; only 3 individuals in a population of 98 F2 River/Tinaja hybrids have 6 caeca. We have quantified fat content, activity, blood glucose, weight loss, and relative gut length in F2 hybrids and are currently using RADseq to identify quantitative trait loci. Our aim is to understand the genetic changes that underlie evolution of metabolism and GI morphology in a low nutrient environment.

84.7 RIESER, JM*; SCHIEBEL, PE; GODDARD, Z; GOLDMAN, DI; Georgia Tech; *jennifer.rieser@physics.gatech.edu*

A robophysical model for limbless locomotion in a heterogeneous environment

Snakes move gracefully through varied terrain, negotiating obstacles such as twigs, rocks, and grasses. Despite the seeming simplicity of this movement, the continuous interaction with the ground coupled with obstacle collisions can give rise to complex dynamics. Work in our lab that explores the interaction of the desert-dwelling sand specialist C. occipitalis with a row of vertical pegs (perpendicular to the initial direction motion) has found that the snake is least likely to apply forces to the pegs along the direction of motion. We have also observed that the snake does not substantially alter its waveform to maneuver through pegs, suggesting that positional control of shape is a reasonable neuromechanical control model. To test this, we built a 13 segment servo-motor-driven snake-like robot (1.13 kg, 80 cm long). Joint angles were commanded via the motors, and low slip translational motion of the robot was achieved by affixing wheels to each segment. To sample robot-peg interactions, the initial shape of the robot was fixed and the robot was placed at different locations within a rectangular region (dimensions set by the peg spacing and distance traveled over one period). The robot position was recorded over several cycles, and in-plane reaction forces were measured via strain gauges on each peg. The forces were complex, with multiple collisions occurring during each transit, but a simple pattern emerged: the distribution of the force orientations for the robot was similar to that of the snakes. This suggests that the animal's interaction with obstacles is dominated by its sand-adapted body wave control mechanics. Intriguingly, video tracking of the robot after transit revealed that it was re-oriented along preferred directions, as might be predicted by wave mechanics.

P2.265 RIFAI, N M*; MYKLES, D L; Colarodo State University; *nadarifai2008@yahoo.com*

Characterization of cyclic nucleotide phosphodiesterases expressed in the decapod crustacean molting gland

Cyclic nucleotides mediate the repression of the crustacean molting gland (Y-organ or YO) by molt-inhibiting hormone (MIH). When MIH levels decline, the YO transitions from the basal to the activated state and the animal enters premolt. During mid-premolt, the YO transitions to the committed state, in which the YO becomes insensitive to MIH. Phosphodiesterases (PDEs) hydrolyze the phosphodiester bond in cAMP and cGMP to AMP and GMP, respectively, and therefore can modify the response of the YO to MIH. In some species, PDE inhibitors decrease molting hormone (ecdysteroid) biosynthesis in the YO *in vitro* , indicating that PDE activity maintains low cyclic nucleotide levels in the activated YO. Increased PDE activity is correlated with a reduced sensitivity of the committed YO to MIH. Contigs encoding nine PDEs (1, 2, 3, 4, 5, 7, 8, 9, &11) were identified in the *Gecarcinus lateralis* YO transcriptome. General and selective inhibitors were used to characterize the PDEs regulating ecdysteroid secretion in the *Carcinus maenas* YO. IBMX, vinpocetine, and zaprinast ± rMIH significantly inhibited ecdysteroid secretion, while EHNA, rolipram, dipyridamole, and BC11-38 did not. This suggests that PDE1 and PDE5/11 are primarily responsible for regulating cAMP and cGMP levels. Analysis of RNA-Seq data using eXpress showed that all nine PDEs were expressed at their highest levels in YO from intermolt *G. lateralis* . mRNA levels decreased during premolt and reached their lowest levels in postmolt. These data suggest that PDEs are regulated posttranscriptionally. qPCR and RNA-Seq will be used to quantify the effects of eyestalk ablation on the mRNA levels of the nine PDEs. Supported by NSF (IOS-1257732).

71.1 RIFFELL, JA*; LAHONDERE, C; OKUBO, R; VINAUGER, C; University of Washington; *jriffell@uw.edu*

Sensory basis of a mosquito-orchid pollination system

Mosquitoes are important vectors of disease, but they are also important pollinators of Platanthera obtusata orchids. These orchids are inconspicuous and blend with the surrounding foliage. Despite being relatively cryptic, these orchids attract a diversity of tiger mosquitoes (Aedes spp.), raising the question of how the orchids attract the mosquitoes. In field experiments we found that mosquitoes are the dominant pollinator of this orchid species. To identify how these orchids attract the mosquitoes, we first examined the orchid scent, which could act as a long-distance cue. Using dynamic sorption methods and GCMS, we found that the orchids emit a scent comprised of common blood-host volatiles as well as other attractants (eg, oviposition). To identify the constituents in the scent that the different Aedes spp. respond to, we used Gas Chromatography linked with Electroantennography (GC-EAG). Results from these experiments showed that the different Aedes species responded to similar constituents in the scent. Behavioral experiments using an olfactometer demonstrated that an artificial mixture of the EAG-active constituents elicited significant attraction compared to the no-odor control. Finally, using two-photon microscopy and bath-applied and genetically encoded calcium indicators we examine how the orchid mixture was processed by the mosquito antennal lobe (AL), primary site of olfactory processing in the brain. AL responses to the olfactory stimuli showed that the orchid mixture was processed in a non-linear manner relative to responses to the individual constituents. Together, these results show that the mosquito olfactory system encodes complex scents differently than individual volatiles, and that scent may play an important role in mediating this unique plant-pollinator system.

106.5 RIGGS, CL*; DOWD, W; LEFEVRE, S; MILTON, S; NILSSON, GE; WARREN, D; PODRABSKY , JE; Portland State Univ, Portland , Loyola Marymount, Los Angeles , Univ of Oslo, Oslo, Florida Atlantic Univ, Boca Raton, Univ of Oslo, Oslo, Saint Louis Univ, St. Louis; *Rclaire@pdx.edu*

Extreme Vertebrate Anoxia Tolerance and Small RNA Expression

Few vertebrates survive weeks to months without oxygen. The most anoxia-tolerant vertebrate known is the annual killifish *Austrofundulus limnaeus*, whose embryos survive over 100 days of anoxia. On-going studies examine mechanisms supporting this tolerance, but comparative studies with other anoxia-tolerant vertebrates are lacking. This study examines the role of small RNAs in the evolution of vertebrate anoxia tolerance. Small RNAs are specific, rapid, and reversible regulators of gene expression, making them interesting candidates for coordinating the entry into and exit from anoxia. Analysis of small RNA expression in *A. limnaeus* embryos revealed specific small RNAs, including several novel sequences, that appear to play important roles in anoxia tolerance. Here we conduct a comparative study on small RNA expression in the most anoxia-tolerant species of major vertebrate lineages, to understand the evolution of extreme anoxia tolerance. The epaulette shark, crucian carp, western painted turtle, and leopard frog were exposed to anoxia and recovery at ecologically relevant temperatures and times, and small RNAs were sequenced from the brain (the most anoxia sensitive organ) prior to, during, and following exposure to anoxia. Small RNA expression patterns differed remarkably between species, indicating that small RNAs have evolved distinctly in each species to support anoxia tolerance. Interestingly, many of the novel sequences identified in *A. limnaeus* do not appear to play a role in the anoxia tolerance of the other species, indicating that *A. limnaeus* possess unique biology, worthy of further investigation.

P1.111 RILEY, SM*; KELLY, MW; LA PEYRE, MK; LA PEYRE, JF; Louisiana State University; *srile14@lsu.edu*

Using Next Generation Sequencing to Identify Local Adaptation to Salinity in the American Oyster, Crassostrea virginica, on the Louisiana Gulf Coast

Salinity plays a key role in the distribution of American oysters, *Crassostrea virginica*, an estuarine species that provides food, shelter, and nursery habitat for numerous species in the Louisiana Gulf Coast. Climate change affects salinity by altering precipitation patterns which in turn alter the frequency, location, and volume of freshwater inflow to estuaries. To improve accuracy of predicted responses of *C. virginica* to climate change, we want to test if oyster populations are locally adapted to salinity. We will use Restriction Site Associated DNA Sequencing (RADseq), to identify potential SNPs responsible for differences in salinity tolerance between two populations of oysters: Vermilion Bay (average salinity 5.6ppt) and Lake Fortuna (average salinity 14.9ppt). To test for differences in the phenotypic response to salinity, we will conduct a reciprocal transplant experiment with oysters spawned from high, medium, and low salinity sites, and measure growth and survival over a one year period. Additionally, we will determine the salinity tolerance by calculating LD_{50} at 6, 12, 18, and 24 ppt salinity with oyster larvae from each parental population. From the RAD sequencing data, we expect to identify SNP's responsible for variation in salinity tolerance across populations. We expect larvae will have lower mortality at their native salinity and that growth will be highest and mortality lowest at outplant sites with similar salinity to the parental stock. Identifying markers associated with salinity tolerance will assist in the selection of breeding stocks for use in restoration or aquaculture.

P2.174 RIMNICEANU, M*; SCIBELLI, A; TRIMMER, BA; Tufts University, Medford, MA; *barry.trimmer@tufts.edu*
Local Thermosensation in the Tobacco Hornworm, Manduca sexta
Thermosensing in animals is the ability to detect temperature or temperature changes. Survival often depends on being able to discriminate thermal events and to locate such stimuli. Although the molecular events associated with thermal transduction have been studied intensely, the encoding of innocuous thermal stimuli remains poorly understood at the level of neural circuits. This can be readily addressed using insects as tractable models because their sensory neurons are identifiable and located peripherally. Here, we describe for the first time behavioral and neural responses to local thermal stimuli in the invertebrate *Manduca sexta* evoked using a novel stimulation technique. After coating the outer cuticle with a dark pigment, discrete and quantifiable thermal stimuli can be delivered to the underlying sensory neurons using a low power infrared laser. As the stimulus intensity was increased *Manduca* responded with increasingly vigorous but local muscular activity. High levels of thermal stimulation elicited a defensive strike response indicating the activation of nociceptive neural transduction pathways similar to those previously described for strong mechanical stimuli. To determine how thermal stimulation is encoded, the activity of afferent neurons was monitored using an extracellular suction electrode on the dorsal nerve of a reduced body preparation. Brief thermal stimuli evoked a transient increase in spike activity. Waveform and cluster analysis of these spikes suggests that only a small number of neurons in the body wall respond to non-damaging temperature changes and that they encode both the duration and intensity of the stimulus.

P2.211 RINDORF, HA*; BLEVINS, B; CAUGHRON, JE; Radford University; *hrindorf@radford.edu*
Phlebotomine Sandfly Collection and Detection of Leishmania in Las Piedras Basin, Madre de Dios, Peru
A commercial mosquito trap was used for the collection of phlebotomine sandflies, known vectors of the parasitic protozoa *Leishmania*. Infected sandflies have been implicated in the transmission of the infectious disease Leishmaniasis to humans throughout the Amazon rainforest. Our study area, located in Las Piedras Basin of the Madre de Dios region of Peru, provided habitat areas to survey insect presence in both forested and deforested locations. A BG-Sentinel mosquito trap with synthetic mammalian scent lures, BG-Lure, and Octenol was used to attract and capture sandflies for this study. The trap was operated overnight in different locations and specimens were removed daily. Extracted DNA was analyzed through polymerase chain reaction (PCR) to confirm sandfly genus and detect presence of *Leishmania*.

P3.19 RIOS, FM*; WILCOXEN, TE; ZIMMERMAN, LM; Millikin Univ.; *frios@millikin.edu*
Does environmental concentrations of imidalocprid impact immune and nervous system development in Rana castesbeiana?
In 1991, Imidacloprid (IMD), a specific neonicotinoid, was introduced to the United States and is now the largest selling insecticide in the world. IMD causes a nearly irreversible blockage of post-synaptic nicotinic acetylcholine (ACh) receptors in the central nervous system of insects. Studies suggest that both chronic and acute exposure to IMD can increase likelihood to multiple disorders in vertebrates. Furthermore, the inhibition of ACh receptors can have a profound effect on an organism's immune response due to ACh's anti-inflammatory effects on macrophages. The tremendous use of IMD in recent years may have added to its soil persistence and storage as well as water contamination. Thus, amphibians are the first group of vertebrates to be directly affected by IMD in their water. We hypothesized that higher levels of acetylcholinesterase (AChE) and lower antibody production will be found in *Rana castesbeiana* tadpoles exposed to environmental concentrations of IMD than in unexposed tadpoles. Over eight weeks, 140 *R. castesbeiana* tadpoles were divided into four groups: two exposed to 100ng/L of IMD and two unexposed. On the fifth week they were injected with either a novel antigen in an adjuvant or the adjuvant alone. After an additional three weeks all tadpoles were euthanized and blood samples taken. We found no significant difference in IgY levels between IMD exposed tadpoles and unexposed tadpoles. We also found no significant difference in AChE levels between exposed and unexposed tadpoles. However, we did find that after three weeks and a single injection *R. castesbeiana* isotype switched from IgM to IgY. As amphibians are often used as indicator species of overall environmental health, and because we found no effect at 100ng/L of IMD in water, IMD may not have drastic effects on vertebrates in the environment at these concentrations.

P2.238 RIPPAMONTI, J*; CROSSLEY, D; Univ. of North Texas; *jrip07@hotmail.com*
The Impact of Hypoxic Incubation on Cardiomyocyte Function in Chicken Embryos
Hypoxic incubation conditions are a recognized stressor during development of many vertebrate species. Previous studies have shown that chronic hypoxia incubation leads to modifications in cardiovascular functioning, which leads to an altered phenotype in juvenile animals. Previously documented changes induced by hypoxic incubation of embryonic chickens include decreased dP/dT and left ventricular ejection fraction. While these features of the hypoxic embryonic heart are recognized, the basis of these changes has yet to be identified. To address this knowledge gap, we focused our investigation on cardiomyocyte contractile function of embryonic chickens at 90% of total development. Our preliminary data demonstrates that the methods classically applied to mammalian cardiomyocytes can successfully used in chicken embryo. Data on contraction index, max force, length-tension relationships, and calcium/contraction relationships.

S6.6 RITERS, LV; Univ. Wisconsin, Madison; *LVRiters@wisc.edu*
Female motivational state and the rewarding properties of hearing male courtship song
Female mating decisions are influenced by the quality of male courtship displays. In many species, males produce vocal signals that are designed to attract females; however not all females are attracted by these signals. One possibility is that environmental factors alter neural mechanisms underlying reward and motivation so that male courtship is attractive when conditions are most favorable for an individual to breed. I will present studies exploring this hypothesis in female European starlings *Sturnus vulgaris*. In starlings the availability of a nest site is critical for breeding. In the breeding season, females housed in aviaries with nest boxes approach males, sing, and displace other females more than females in aviaries without nest sites. They also tend to have higher estradiol concentrations than females without boxes. These differences occur even in females that do not enter and defend an available box. In contrast, the affective state induced by hearing male courtship song depends on whether a female is actively defending a nest site. Using a classic conditioned place preference test of reward we found that hearing male song induced reward in females that defended nest boxes but not in females that did not. These differences were accompanied by differences in dopamine- and opioid-related genes and proteins in the medial preoptic nucleus, ventromedial hypothalamus, and nucleus accumbens. This suggests that the mere presence of a nest site initiates breeding-related changes in physiology and behavior, but possession of a nest site induces additional neural changes to increase the reward value of male courtship song. Overall, these findings suggest that environmental factors alter motivation and reward neural systems to fine-tune female responses to male courtship song to maximize breeding success.

66.1 RIVERA, G; Creighton University; *gabrielrivera@creighton.edu*
An examination of the relationship between locomotor mode and patterns of fore- and hindlimb symmetry in semiaquatic freshwater turtles (Family: Emydidae)
Understanding how selective forces influence patterns of symmetry remains an active area of research in evolutionary biology. One hypothesis, which has received relatively little attention, suggests that the functional importance of morphological characters could influence patterns of symmetry. Specifically, it posits that features with greater functional importance should be more symmetrical. The aim of my research was to examine the patterns of fluctuating asymmetry (FA) present in the limb bones of semiaquatic freshwater turtles from the family Emydidae. Emydid turtles primarily employ a hindlimb-dominant swimming style, suggesting that hindlimbs should display lower levels of FA. However, within the family, some species are more terrestrial. As terrestrial locomotion places more equal importance on fore- and hindlimbs, such behaviors may minimize differences in FA. This dichotomy in propulsive modes provides an excellent test of the biomechanical hypothesis of symmetry. I measured the length of the proximal limb bone of the left and right fore- and hindlimbs (humerus and femur). These data were used to calculate asymmetry (FA) in each set of bones for each species examined. I then used these data to test two predictions. First, I tested whether within emydid turtles, the hindlimbs would display greater symmetry than the forelimbs. Second, I tested whether such patterns differed between highly aquatic species and species with more terrestrial tendencies. Findings indicate that within emydid turtles, symmetry is higher in hindlimbs, thus supporting the morphofunctional hypothesis. Differences consistent with the differing demands of aquatic and terrestrial locomotion were also detected between the subfamilies.

P1.116 RIVERA-ORDONEZ , JM*; SALAZAR-NICHOLLS , MJ; WARKENTIN, KM; DELIA, J; University of Washington, Seattle, Pontificia Universidad Catolica, Quito, Boston University, Boston University; *juanamariariverao@gmail.com*
The adaptive value of delayed hatching in glassfrogs
Across animals, embryos can hatch in response to environmental cues. Early hatching can improve embryo survival when eggs are in danger, but may come at a cost to the larval life-stage. Thus, understanding the adaptive value of hatching plasticity requires evaluating the costs and benefits that characterize selective trade-offs. Several species of glassfrogs (Centrolenidae) can hatch as early as 7 days in response to predators, dehydration, and parental abandonment, or delay hatching to 20 days under good conditions. We measured two fitness correlates, for survival and growth, to test the adaptive value of delayed hatching in five species: *Cochranella granulosa*, *Hyalinobatrachium fleischmanni*, *Hyalinobatrachium colymbiphyllum*, *Teratohyla pulverata*, and *Teratohyla spinosa*. Hatchlings fall from arboreal eggs into streams and must dive to the bottom to escape predatory fish. We measured diving performance for early and late hatchlings to infer predation risk. As tadpoles cannot benefit from external food resources until they reach feeding competence, we quantified the onset of feeding and compared gut-coil development in siblings of different hatching ages. Older hatchlings dove faster and began feeding sooner after hatching than did younger individuals, suggesting that delayed hatching is advantageous for escaping predators and reducing lag-time in exotrophic-based growth of larva. However, early hatchlings began feeding at a younger age than did older hatchlings, at which point they had more developed gut-coils than their unhatched siblings, indicating that younger hatchlings accelerate development to feeding competence. This study provides insight on the selective trade-offs that favor hatching plasticity in glassfrogs.

P2.255 RIX, AS*; O'BRIEN, KM; University of Alaska Fairbanks; *asrix@alaska.edu*
Polyglutamine and Glutamic Acid Repeats Within Hypoxia-Inducible Factor-1α in Antarctic Notothenioid Fishes May Alter the Hypoxic Response
The long evolution of the Antarctic perciform suborder of Notothenioidei in the stable, cold, oxygen-rich waters of the Southern Ocean may have eliminated their capacity to respond to hypoxia, especially in Channichthyidae family (icefishes), which lack hemoglobin and are benthic, sedentary fishes with low activity levels. We hypothesized that icefishes may have lost the capacity to induce protective mechanisms against hypoxia, and specifically, that hypoxia-inducible factor-1α (HIF-1α) may be functional in red-blooded notothenioids but not in icefishes. HIF-1α cDNA was sequenced in heart ventricles of the red-blooded notothenioid *Notothenia coriiceps* and the icefish *Chaenocephalus aceratus* using 3′ and 5′ rapid amplification of cDNA ends (RACE). HIF-1α cDNA in N. coriiceps is 4500 base pairs (bp) long and encodes 755 amino acids (AA). In C. aceratus HIF-1α is 3576 bp long and encodes 779 AA. All functional domains of HIF-1α are conserved when compared to HIF-1α in other teleosts, but HIF-1α contains a polyglutamine/glutamic acid (polyQ/E) repeat 9 AA long in *N. coriiceps* and 34 AA long in *C. aceratus*. Sequencing of this region in 4 additional species of notothenioids revealed that the polyQ/E repeat varies in length based on phylogeny. Icefishes, the crown species of notothenioids, contain the longest repeats of 16-34 AA long, whereas the basal, cold-temperate notothenioid, *Eleginops maclovinus*, contains a repeat of 4 AA. PolyQ/E repeats could cause protein misfolding and/or altered mRNA structure, monopolizing RNA processing proteins, resulting in decreased protein production. Without functional HIF-1α, the hypoxia response may be blunted, potentially lowering thermotolerance in icefishes with longer HIF-1α polyQ/E repeats compared to red-blooded notothenioids.

127.2 ROBART, AR*; WATTS, HE; Loyola Marymount University, Los Angeles, CA; *arobart@lmu.edu*
Food Reduction Increases Daytime Activity and Corticosterone in a Facultative Migrant
Facultative migration is characterized by unpredictable, highly variable patterns of movement that vary in both direction and timing across years. For many facultative migrant species it is hypothesized that a reduction in food availability triggers migratory behavior in an attempt to locate more favorable habitat. Corticosterone may mediate this transition, as increased corticosterone levels are associated with increased locomotor and foraging activity in both obligate and facultative migrants. Pine siskins (*Spinus pinus*) are a nomadic, irruptive migratory finch whose primary food source (conifer seeds) is also characterized by a high degree of spatial and temporal variability in abundance. We examined the effect of reduced food availability on migratory behavior and physiology and whether changes in behavior and/or physiology were associated with increased corticosterone levels. We measured locomotor activity, body mass and fat deposition, and circulating corticosterone levels for birds that experienced a food restriction and birds with *ad libitum* access to food. Food-restricted birds had higher daytime, but lower nighttime, activity levels compared to control birds. Corticosterone levels were also higher in food-restricted birds relative to control birds but returned to baseline levels within two weeks of returning to *ad lib* food. These results suggest that a reduction in food availability increases locomotor activity, which is associated with an increase in corticosterone; these results are similar to those from another facultative migrant (red crossbills). Pine siskins can migrate diurnally and nocturnally, however, reduced food availability may result in activity shifting to daylight hours, as this would facilitate assessment of new habitat to determine resource abundance.

P3.192 ROBERGE, TM*; WIBBELS, T; Univ. of Alabama at Birmingham; *troberge@uab.edu*
Relative period of temperature sensitive is dependent upon specific incubation temperature
Temperature-dependent sex determination (TSD) is a form of sex determination in which incubation temperature during the temperature sensitive period (TSP) determines sex. Previous studies have determined the TSP coincides with the approximate middle third of embryonic development between embryonic stages 14 and 20 of *Trachemys scripta*. The majority of these studies used constant temperature incubation with a shift to a single temperature during the middle third of incubation to determine the period of temperature sensitivity. There is also evidence that the incubation temperature before the shift may influence the length of the TSP. Additionally, a larger magnitude shift near the end of the TSP can result in greater abundance of sex reversal. It is currently unknown whether the TSP under fluctuating incubation temperatures behave in a similar pattern seen in constant temperature studies or whether larger shifts near the end of the TSP could extend the relative period of temperature sensitivity. In this study, we examined the effects of multiple temperature shift magnitudes as well as the effects of fluctuating incubation temperature on the end stages of the TSP in *T. scripta*. Eggs were placed under three treatment temperatures: 1) Constant 31°C, 2) 26°C ± 3°C, and 3) 31°C ± 3°C. Eggs were dissected frequently to determine the stage of the embryo and eggs were shifted to incubators with temperatures known to produce the opposite sex at stages before, during, and after the known end of TSP. Eggs were then allowed to incubate until stage 26 where they were sexed. The results of this study have implications in both the physiology of TSD as well as conservational implications when trying to model sex ratios by comparing field data to controlled laboratory studies.

112.3 ROBERTS, NS*; MENDELSON, TC; Univ. of Maryland, Baltimore County; *nat17@umbc.edu*
Male Mate Choice Contributes to Behavioral Isolation in Sexually Dimorphic Fish with Traditional Sex Roles
Female mate choice is usually implicated in behavioral isolation between species with divergent male ornaments. However, males in many sexually dimorphic species with traditional sex roles also demonstrate mate choice, suggesting they could also play an important role in behavioral isolation between species. Many examples of male choice demonstrate preferences for indicators of female fecundity that often do not vary across species, effectively excluding male mate choice from any role in the maintenance of species boundaries. But, male mate choice for homotypic females has been observed as well, suggesting that at least in some cases, male choice contributes to behavioral isolation. We therefore test the role of male mate choice in the maintenance of species boundaries for two species of darters (Percidae: *Etheostoma*), sexually dimorphic freshwater fish with visually elaborate males and drab females. Dichotomous choice assays using sympatric darters *Etheostoma barrenense* and *E. zonale* tested male preference for size-matched, gravid conspecific and heterospecific females, thus reducing the possibility that males were selecting for general indicators of fecundity. Results show that males of both species strongly prefer conspecific females and that male preference for conspecific females is as strong as female preference for conspecific males in *E. barrenense*. Calculating the accumulated contribution of male mate choice, female mate choice, and male-male competition to behavioral isolation suggests that male mate choice may have a larger role in the maintenance of species boundaries than generally predicted in this system. Our results suggest that the contribution of male choice to behavioral isolation may be underestimated in sexually dimorphic species with elaborate males.

P1.75 ROBERTS, AS*; GOFORTH , RR; Purdue University ; *rober231@purdue.edu*
Niche Partitioning Based on Temperature Gradients in Estuarine Cyprinodontiform Fishes (Families: Fundulidae, Cyprinodontidae, and Poeciliidae)
Fish communities are often composed of related species that vie for similar resources, thus facing competitive exclusion. In many cases, resource and niche partitioning play a role in supporting coexistence among species. These processes can be facilitated by several strategies such as trophic divergence, utilizing varying prey capture techniques, or occupying different microhabitats based on physio-chemical gradients. Fishes of the family Fundulidae provide an ideal model for studying this phenomenon as they are globally distributed and occupy diverse freshwater, brackish, and marine habitats. *Fundulus grandis*, *F. majalis*, and *F. heteroclitus* are among multiple killifish species found along the East Coast of the United States; specifically, these three species and related species *Cyprinodon variegatus* and *Poecilia latipinna* commonly occupy estuarine communities in Southeastern United States. Niche partitioning within killifish communities based on salinity tolerance has been thoroughly examined, but little experimentation has been completed to determine if other environmental factors play a similar role in reducing interspecific competition. Based on field observation and previous study we hypothesize that water temperature may be an important environmental factor that supports niche partitioning within these estuarine communities. Using a series of mesocosm experiments in monocultures and simulated communities, we plan to determine if killifish and related species prefer and/or specialize in occupying habitats of differing temperatures to reduce competition and facilitate niche partitioning.

74.4 ROBERTS, KT*; RANK, NE; DAHLHOFF, EP; STILLMAN, JH; WILLIAMS, CM; Univ. of California, Berkeley, Sonoma State Univ., Santa Clara Univ.; *kevrob@berkeley.edu*

The effects of snow cover on overwinter physiology of a montane insect

During winter, organisms are faced with multiple concurrent physiological challenges, including extreme cold and limited resources. During dormancy individuals rely on energy reserves accumulated during the resource-abundant summer months. Metabolic rate dictates rate of consumption of stored energy reserves, and is influenced strongly by temperature. For organisms that overwinter in subnivean (beneath-snow) spaces, temperature is modulated by snow cover, with snowy years being relatively warm and stable, while dry years are cold and variable. Snow thus alleviates the energetic cost of a stress response at the expense of a higher overall metabolic rate. Higher overall metabolic rate will deplete energy reserves, which are important because remaining reserves in spring determine future reproductive success. The willow beetle *Chrysomela aeneicollis* lives in high elevation habitats in the Sierra Nevada Mountains, where it overwinters in leaf litter below its host plant. To test the hypothesis that snow modulates winter energy use, we placed field-caught individuals under soil in plots exposed to natural snow cover or sheltered from snow. After seven months, survival was assessed and whole body lipid profile was measured using thin layer chromatography (TLC-FID). Survival did not differ between snow and no-snow conditions. Lipid stores decreased over the course of winter in both conditions, and beetles in the warmer, snowy conditions had significantly lower lipids at the end of winter compared to those exposed to environmental temperatures. This suggests that variation in snow cover will impact overwintering energetics of ectotherms.

37.7 ROBERTSON, J. M.; NAVA, R. A.*; KAISER, K; VEGA, A; California State University, Northridge, San Diego State University, Pomona College, University of Costa Rica, San Jose; *rnavalanderos@sdsu.edu*

Local Standard of Beauty: Non-clinal Assortative Mating Along a Red-eyed Treefrog Cline

Intraspecific clines provide key insights into the mechanisms that mediate lineage divergence. We examine the extent to which premating reproductive isolation varies along a genetic and phenotypic cline of populations of red-eyed treefrogs (Agalychnis callidryas) in Costa Rica and Panama. Our study had two aims: first, to quantify premating reproductive isolation (RI) using female mate choice and, second, to examine the relationship between reproductive isolation and phenotypic and genetic distance. We assessed female choice using a two-choice Y-design enclosure in three populations (Gamboa, Panama; Manzanillo and La Selva, Costa Rica). Females from each population were presented with a choice between a local and non-local male stimulus. We tested 38-40 females per population; 18-20 trials were conducted with the local and one non-local male and 20 trials with the alternate non-local male. For the male stimulus, we used plasticine models that were painted to represent focal populations and mounted on a rotating platform to simulate movement. Models were paired with population-appropriate acoustic stimuli. Choice was documented within a 10-minute trial. Log-linear modeling showed that females preferred local males, but assortative mating was not clinal. We quantified RI in JMATING and quantified genetic and phenotypic distances in calls and color as Euclidean distance. RI does not vary with genetic or phenotypic diversity. We discuss our finding of non-clinal assortative mating in red-eyed treefrogs in light expected levels of reproductive isolation for intraspecific populations.

P1.10 ROBERTSON, JC; Westminster College, PA; *robertjc@westminster.edu*

The Articulate Alligator: Projects for a Comparative Anatomy Course

Two projects in an upper division comparative anatomy course centered on the skeleton of the American alligator (*Alligator mississippiensis*). The first project involved lab groups disarticulating full alligator skeletons from harvested carcasses, followed by isolating, identifying and cataloging the individual bones. Students developed protocols for treating the carcasses in order to separate and clean the bones. Students then identified all the isolated skeletal components, created schemes for grouping and displaying the materials, and produced an inventory of the bones. The second project took place the next time the course was offered and involved articulating a complete alligator skeleton from a full set of individual bones. These students had to properly articulate all bones, devise methods for permanently joining elements together, and conceive of and execute a presentation pose and mounting of the skeleton. This project culminated in display of the articulated specimen, along with a poster describing the process, at an undergraduate research conference. These activities were intended as engaging opportunities to contribute to student understanding of vertebrate/reptilian bones and joints - for example, enhancing appreciating of how bones interact with each other to support the animal's body and permit movement. The projects each culminated as material that can be used by other students and classes to help understand skeletal anatomy.

P2.50 ROBINSON, CD*; GIFFORD, ME; University of Central Arkansas; *cdrobinsontx@gmail.com*

The use of a colorful morphological signal as a status symbol in the prairie lizard, Sceloporus consobrinus

In many taxa, colorful morphological features are used to advertise individual quality to conspecifics. Variation in these traits can lead to variation in reproductive success, therefore resulting in directional selection on this signal. In the prairie lizard, *Sceloporus consobrinus*, males exhibit bright blue patches on their abdomens and throats, the ontogeny of which is related to increased testosterone levels at sexual maturity. Patch size and color is variable between individuals, but it is currently unknown if variation in size and color is related to variation in testosterone levels. Since many traits that signal individual quality, and therefore influence reproductive success, are related to testosterone levels (e.g. performance, territory size), it would seem that these patches would serve as an honest indicator of quality themselves. Here, we use a population of prairie lizards in central Arkansas to address this question. We collected patch color and size measurements, testosterone levels, and endurance times on 45 male lizards, and territory size measurements on 45 males and 51 females (female overlap serves as a good proxy for male reproductive success) in the summer of 2016. Using multiple regression and path analysis, we examine how patch color serves as an indicator of male quality (as measured by endurance, territory size, and reproductive success) and how testosterone mediates the expression of this signal.

96.4 ROBINSON, SE*; BOTERO, JM; FINGER, JW; HOFFMAN, AJ; ZHANG, Y; KAVAZIS, AN; CRISTOL, DA; WADA, H; Auburn University, College of William and Mary; *ses0065@auburn.edu*

Lipid Peroxidation and Antioxidant Capacity as Indicators of Oxidative Stress in Mercury-exposed Zebra Finches

Oxidative stress occurs as a result of an imbalance between antioxidants and reactive oxygen species (ROS) and can be detrimental to an organism. Methylmercury, a potent environmental contaminant, has been shown to contribute to oxidative stress. More specifically, methylmercury exposure has been shown to both decrease antioxidant capacity and increase ROS production. We hypothesized that long-term exposure to methylmercury through diet results in accumulation of oxidized lipids (i.e., lipid peroxidation) and decreases superoxide dismutase (SOD) levels. In this regard, SOD2 is an endogenous antioxidant enzyme that is found in mitochondria and is considered to be one of the first lines of defense against increased ROS production. To test this, captive zebra finches were exposed to 1.2 ppm methylmercury via diet throughout their lifetimes. Using Western blots, 4-HNE (hydroxynonenal) and SOD2 were quantified in liver, pectoralis muscle, and brain. Two regions of the brain, the cerebellum and arcopallium, were used for analyses. The cerebellum was used because of its striking similarities regarding mercury toxicity in the human brain, and the arcopallium was selected because our previous work indicated that the robust nucleus of the arcopallium is particularly vulnerable to dietary mercury. We predict birds exposed to methylmercury will experience higher oxidative stress as indicated by higher levels of 4-HNE and lower levels of SOD2 compared to controls.

P2.63 ROCK, AN*; STEPHENSON, TQ; DUBUC, TQ; MARTINDALE, MQ; Whitney Laboratory for Marine Science, University of Florida; *arock@bowdoin.edu*

The Cnidarian Hox Gene Anthox6a Controls the Site of Gastrulation in the Sea Anemone, Nematostella vectensis

Hox genes are highly conserved group of transcription factors that are responsible for patterning along a primary axis during development and are found in all bilaterians, an expansive clade representing over 99% of metazoan life. Cnidarians, such as anemones and corals, represent the only phylum outside of the Bilateria to have Hox genes, making them an important sister group for studying Hox gene evolution. Using embryos of the sea anemone, *N. vectensis*, we show using qPCR that Anthox6a is maternally expressed, suggesting that it may have a role in early development. Furthermore, Anthox6a is shown to be asymmetrically expressed along the future site of gastrulation when visualized with *in situ* hybridization. When Anthox6a is prevented from being expressed through the injection of eggs with an antisense morpholino, the treated embryo fails to gastrulate and endomesodermal markers are not expressed. This suggests that Anthox 6a has a fundamental role in allowing gastrulation to occur in cnidarians. Furthermore, when Anthox6a mRNA is injected ectopically into random blastomeres at the 8-32 cell stage, a second site of gastrulation including endomesodermal marker expression, is formed at the site of injection. This is the first case when ectopic expression of a Hox gene is able to establish a new body axis. This suggests that anterior Hox genes may have had fundamental roles in establishing the primary body axis in the ancestor of cnidarians and bilaterians.

P3.240 RODEMOYER, EM*; ROBERTSON, JC; Westminster College, PA; *erodemoyer32@gmail.com*

Quantifying Electrosensory Ampullae on the Rostrum of Developing Paddlefish

The dramatic rostrum of the paddlefish (*Polyodon spathula*) begins to grow several weeks after hatching, and within a period of several more weeks, this extension of the cranium has grown to represent one-third of the total body length of the juvenile fish. This remarkable positive allometric growth pattern coincides with elaboration of large numbers of well-described electrosensory ampullae on the rostrum surface. Paddlefish use electrosensation in prey (plankton) acquisition and in navigating their environment. We quantified changes in rostrum ampullae number during juvenile development in order to better appreciate sensory development in this species. Rostrums of five size classes of juvenile paddlefish were imaged by fluorescence microscopy and dorsal rostrum ampullary pores were counted using an image analysis program. Results indicate: 1) rostrum ampullae exhibit bilateral symmetry, and; 2) the number of ampullae does increase dramatically as juvenile fish grow and the rostrum extends. Growth of the rostrum provides a structural basis for increasing ampullary numbers, and more ampullae likely contribute to enhanced electrosensory capacity. In development, as ampullae are added, they must be integrated into the sensory transmission and processing systems. Therefore, the increase seen in rostrum ampullary numbers suggests that paddlefish may provide an interesting model for investigating vertebrate sensory plasticity and integration.

S6.9 RODRIGUEZ-SALTOS, CA; Emory University; *bio.carodrgz@gmail.com*

Before songbirds are senders, they are receivers

Receivers are motivated to approach courtship signals; in other words, these signals have incentive salience to the receivers. Though the concept of a receiver is commonly associated in the literature with that of a mate seeker, young songbirds that are learning to sing by imitating conspecifics are also receivers. To these juveniles, the songs from tutors, that is, from birds that are being imitated, have incentive salience. The mechanisms underlying ascription of incentive salience to tutor song are poorly understood. Here, I review studies on tutor choice and discuss possible mechanisms by which tutor song acquires incentive salience. In at least some species, juveniles imitate individuals with which they have a strong social bond, such as the father. Such cases suggest that social reward plays a role in ascribing incentive salience to song. In addition, experiments using birds reared in isolation from conspecific song have shown that juveniles imitate songs that have acoustic features that are typically found in conspecific song. Those studies suggest that such features are attractive to juveniles regardless of their social experience. The relative contributions of social reward and species-typical acoustic features to the incentive salience of a song can be determined using methods such as operant conditioning. For example, juvenile songbirds can be given control over the playback of songs that differ in a given attribute, such as acoustic similarity to the song of the father. The juveniles will more frequently elicit playback of the songs that are most attractive to them. Investigating the mechanisms that contribute to the incentive salience of tutor song will broaden our understanding of mate choice in songbirds, because song preferences in learners may ultimately determine what will be sung to potential mates.

8.3 ROEGNER, ME*; CHEN, HY; WATSON, RD; University of Alabama at Birmingham; *mzappe@uab.edu*

Cloning of a cDNA Encoding a Sarco/endoplasmic Reticulum Ca^{2+} ATPase (SERCA) from Y-organs of the Blue Crab (Callinectes sapidus) and Spatial and Temporal Patterns of SERCA Expression

Stage-specific increases in intracellular free Ca^{2+} have been shown to stimulate ecdysteroid production in the molting glands (Y-organs) of crustaceans. Intracellular Ca^{2+} levels are regulated by proteins intrinsic to the plasma membrane and membranes of organelles. These include Ca^{2+} pumps, e.g., plasma membrane calcium ATPases (PMCAs) and sarco/endoplasmic reticulum calcium ATPases (SERCAs). In order to better understand the role of intracellular calcium signaling in the regulation of ecdysteroidogenesis, we used a PCR based cloning strategy (RT-PCR followed by 3′- and 5′-RACE) to clone a full length cDNA encoding a putative SERCA protein from the Y-organs of the blue crab (*Callinectes sapidus*). The cDNA includes an optimal translational initiation sequence, a start codon, and a 2488-bp open reading frame that encodes an 829-residue protein with 91 percent identity to comparable crustacean SERCA sequences. Phylogenetic analysis shows the blue crab SERCA protein to cluster with other arthropod SERCAs. An assessment of spatial distribution showed the SERCA transcript to be widely distributed across tissues of the crab. Furthermore, SERCA transcript levels were analyzed in Y-organs using quantitative PCR. Transcript abundance was assessed after Y-organs were activated by eyestalk ablation, and throughout a natural molting cycle. Stage specific changes in SERCA cDNA levels provide insight into the role of Ca^{2+} signaling and intracellular Ca^{2+} regulatory proteins in endocrine regulation of crustacean molting.

P1.223 ROER, RD*; DILLAMAN, RM; Univ. of N.C. Wilmington; *roer@uncw.edu*

Silicon - potential role in postmolt calcification in the blue crab Callinectes sapidus

Studies on a variety of taxa have suggested a possible role for silicon in the early stages of calcium carbonate and calcium phosphate biomineralization. We examined pre- and postmolt exoskeleton from the blue crab *Callinectes sapidus* using scanning electron microscopy and energy dispersive analysis of x-rays. The data reveal the presence of silicon (presumably silica) in the premolt carapace. Silicon is displaced or obscured by calcium as calcification begins during postmolt. Silicon continues to be detected in areas that have not yet undergone calcification. The involvement of silicon in some aspect of calcification is supported by the absence of silicon at any molt stage in the arthrodial cuticle, tissue which never undergoes calcification. The pattern of silicon distribution suggests that it plays a role in calcium carbonate nucleation or in the stabilization of amorphous calcium carbonate during the initial phase of calcification.

P1.31 ROGERS, LS*; GIUFFRIDA, B; LE ROUX, V; MENSINGER, AF; University of Minnesota Duluth, Wareham Middle School, Woods Hole Oceanographic Institute; *roger710@d.umn.edu*

Visualization of the Oyster Toadfish (Opsanus tau) Anterior Lateral Line via Micro-CT

Recent experiments have characterized the frequency sensitivity and range of the Oyster Toadfish (*Opsanus tau*) anterior lateral line which functions both in prey detection and sound localization. The locations of both the superficial and canal neuromasts have been established and the goal of this study was to develop an external sensory map that combines electrophysiology characteristics with neuromast location. To determine the precise three-dimensional location and sensory axis of the neuromasts, micro computed tomography (CT) scanning was conducted. Micro-CT scanning is a three-dimensional x-ray imaging technique that offers the ability to visualize the lateral line without damage to the lateral line. To conduct this experiment, the anterior portion of the Oyster Toadfish was stained with a 0.3% phosphotungstic acid (PTA) solution to enhance scanning. The Oyster Toadfish was scanned with a Bruker Skyscan 1272 micro-CT at a pixel size of 12.9 µm. Three-dimensional reconstruction and corrections for beam hardening and ring artifacts were made using the Skyscan NRecon software. Reconstructions of micro-CT scanning made it possible to visualize the finger like projections of the superficial neuromasts, determine the axis of orientation and quantify neuromasts along the anterior lateral line of the Oyster Toadfish.

P1.20 ROGERS, DJ*; HENDRICK, M; WATSON, GM; SMITH, KM; University of Louisiana at Lafayette; *djr8585@louisiana.edu*

Calcium Signaling in GABAergic-Cortical Astrocyte coCulture is influenced by Fibroblast Growth Factor Receptor 1 (FGFR1)

Astrocytes in the cerebral cortex have many functions that support neuronal integrity. One such function is maintaining ionic homeostasis of the extracellular fluid. Alterations in astrocyte function could affect the associated neuronal field, in turn, effecting neuronal activity or neuronal survival. We previously published that transgenic$FGFR1^{Flox/Flox;NestinCre}$ mice have a decreased number of cortical interneurons. Interneurons grown on $FGFR1^{Flox/Flox;NestinCre}$ mouse astrocytes presented smaller soma size and fewer dendritic processes than their littermates. The physiology underlying this morphology is unknown. One possible hypothesis is $FGFR1^{Flox/Flox;NestinCre}$ cortical astrocytes are unable to maintain the proper extracellular environment for proper function and/or survival of these interneurons. To investigate the role FGFR1 has in neuronal-astrocyte physiology, Gad-67 GFP+ labeled GABAergic inhibitory interneurons were grown on a feeder layer of $FGFR1^{Flox/Flox;NestinCre}$ knockout astrocytes. Using Fluro3AM, videos recording intracellular calcium signaling were analyzed using Image J. $FGFR1^{Flox/Flox;NestinCre}$ had significantly fewer calcium peaks when compared to control. ($FGFR1^{Flox/Flox;NestinCre}$ knockout astrocytes Mean=4.75 ± 3.38 peaks, FGFR1control astrocytes Mean=20.13 ± 3.38, p=0.0063*) To be further investigated was the observation that the calcium peaks of cocultured interneurons on the knockout astrocytes were lower amplitude than control. These results suggest that there are definitely significant differences when interneurons are applied to $FGFR1^{Flox/Flox;NestinCre}$ astrocytes, indicating the importance of the astrocyte-neuron interaction.

74.2 ROMNEY, A LT*; PODRABSKY, J E; Portland State University; *arom2@pdx.edu*

Gene expression during development and diapause in a vertebrate extremophile

The annual killifish, *Austrofundulus limnaeus*, has adapted to survive in harsh and unpredictable environments by entering diapause during embryonic development. Diapause is a pre-programmed exit from normal development that occurs midway through the embryonic period and is characterized by a severe metabolic and developmental arrest. Embryos may also follow an alternative phenotypic trajectory where individuals can instead "escape" entry into diapause and develop continuously to the completion of development. Developmental phenotype is influenced by maternal provisioning and incubation temperature of the embryos. Incubation at 30°C results exclusively in escape embryos while incubation at 20°C results in exclusively diapausing embryos. Previous work has illustrated unique morphological, physiological, biochemical and metabolic profiles in the two developmental trajectories, but these pathways have yet to be described at the gene expression level. We have generated profiles of mRNA gene expression using Illumina RNAseq during early development in embryos developing on both diapause and escape trajectories. These data suggest diapause- and escape-specific gene expression programs that support the entrance into diapause and the high tolerance of environmental stress exhibited by diapausing embryos. These patterns of gene transcription provide a global perspective on genes that may be critical for regulation of metabolic dormancy and survival of anoxia and desiccation. These data are now being used to generate and test the role of specific genes and gene products that regulate diapause and stress tolerance at the organismal level.

16.1 ROSARIO, MV*; SUTTON, GP; PATEK, SN; SAWICKI, GS; Brown University, University of Bristol, Duke University, North Carolina State University and University of North Carolina at Chapel Hill; *michael_rosario@brown.edu*

The springs of time-limited bullfrog jumps and slow-preparation grasshopper leaps are tuned to their muscle dynamics

Springs in series with muscles store maximal energy when muscles undergo slow, forceful fixed-end contractions, such as the long preparation for a locust jump. However, some organisms, such as bullfrogs, load their springs quickly and, therefore, cannot achieve maximal force capacity due to the force-velocity tradeoff of muscle. Here we ask if the spring constants measured from time-limited organisms (bullfrog: *Lithobates catesbeiana*) are tuned to maximize energy storage for sub-maximal force production, whereas for non-time limited organisms (grasshopper: *Schistocerca gregaria*), they are tuned to maximal force production. By using a dynamic muscle-spring simulation, we identified the optimal spring stiffness of the time-limited jumper (bullfrog) and non time-limited jumper (grasshopper), and we compared these with actual measurements of spring stiffness. We found that when spring-loading is time-limited, optimal spring stiffness is lower than when it is not. We also found that the measured spring stiffness of tendons in bullfrogs more closely resembles the optimal spring constant at biologically-relevant loading times (50 ms) than at maximum force production (t > 300 ms). Conversely, the measured spring constant in grasshoppers matches the optimal spring constant at maximum force production (t > 300 ms). These findings demonstrate the importance of combining muscle dynamics and comparative analyses of spring mechanics when probing the limits of energy storage in muscle-spring systems and placing these dynamics in the context of how animals use these systems in their normal activities.

90.3 ROSE, CS*; CAHILL, J; James Madison University; *rosecs@jmu.edu*

Effects of T4 and T3 on cartilage growth and shape change in Xenopus tadpole

To study the effects of thyroid hormones (TH) on frog metamorphosis, researchers often apply TH to tadpoles to induce metamorphosis precociously. However, precociously induced remodeling might not resemble natural remodeling because remodeling might be induced before larval tissues are fully competent to respond to TH or before they attain the shapes at which natural remodeling starts. Also, remodeling induced in young tadpoles occurs during a period of exceptionally fast growth, and fixed concentrations of T3 or T4 are unlikely to have the same effects as the changing T3 and T4 levels in natural metamorphosis. This study aims to clarify how precociously induced remodeling affects the size and shape changes in two pharyngeal arch cartilages, Meckel's cartilage (MC) and ceratohyal (CH). Xenopus tadpoles were pretreated at early, mid and late tadpole and early metamorphic stages with 1 mM methimazol to arrest them at different starting stages (NF 46, 53, 57 and 59/60). The tadpoles were subsequently treated with 0, 1, 5, 10, or 50 nM T3 or T4 as well as 1 mM methimazol and 10 uM iopanoic acid, which prevent the tadpoles from making their own TH and converting T3 or T4 into another form of TH. Specimens were photographed before and after treatments and then fixed and stained for cartilage and bone. The MC and CH were dissected out and photographed, and the photographs were landmarked and digitized to calculate final dimensions. Initial dimensions were estimated from start photographs using equations from a previous study of untreated individuals that relate external to internal dimensions. The shape changes induced at NF 46 are significantly different from natural metamorphosis due to early tadpole growth, T4 has different effects from T3, and though changes induced at higher stages are more like natural remodeling, some produce abnormalities.

P3.67 ROSENCRANS, RF; PERKINS, K; LESLIE, CE; RICHARDS-ZAWACKI, C; GORDON, WC; BAZAN, NG; FARRIS, HE*; LSU School of Medicine, New Orleans, Univ. of Pittsburgh; *hfarri@lsuhsc.edu*

Visual Sensitivity and Optics of Nocturnal and Diurnal Frogs: A Comparative Approach

Studies of the visual system often employ anuran models, yet few data indicate the degree of variance in retinal anatomy and physiology across species. Variance across species is most likely driven by different diel niches, as light intensity varies by 6 orders of magnitude. In the present study, we examined the light sensitivity and optics in nocturnal (*Hyla cinerea* and *Rana pipiens*) and diurnal frogs (*Oophaga pumilio* and *Mantella viridis*). Using electroretinogram recordings, the minimum light intensity necessary to elicit second order neural responses was determined (scotopic B-wave threshold). In addition, photopic B-wave threshold (i.e., cone response) was determined by introducing constant background illumination. Nocturnal species require approximately 1.5 log units less light to elicit scotopic B-waves as compared to diurnal counterparts. No variance is observed in photopic thresholds, indicating increased visual sensitivity may be limited to rod photoreceptors (PR). In a third experiment, we characterized optical sensitivity. Pupillary diameter was determined using infrared photography, focal length was measured in flash-frozen eye sections, and PR outer segment diameter and length were measured in plastic sections (confirmed with Nomarski microscopy in frozen sections). These measurements were used in the Land sensitivity equation (1981) to estimate optical sensitivity. Results show a strong correlation between optical and physiological sensitivity, providing compelling evidence of variance in the peripheral sense organ, which should be taken into account when building models of central visual processing.

P2.251 ROSS, TT; OVERTON, JD; KINSEY, ST*; Univ. N. Carolina Wilmington; *kinseys@uncw.edu*

Hypoxia Acclimation and β-GPA Treatment Lead to Similar Changes in Cellular Energy State that Enhance Basal Metabolic Rate and Hypoxic Exercise Tolerance

Acclimation to hypoxia is associated with changing of the set point of high energy phosphate molecules in skeletal and cardiac muscle, characterized by a reduced phosphocreatine (PCr) to ATP ratio. This response is associated with enhanced hypoxic exercise endurance. β-guanidinopropionic acid (β-GPA) supplementation decreases the PCr/ATP resulting in an energetic challenge that is similar to both exercise and acclimation to hypoxia. In this study, we administered β-GPA to mice for 2 or 6 weeks, and investigated the effect on muscle energetic status, body and muscle mass, basal metabolic rate (BMR), and normoxic and hypoxic exercise tolerance (NET and HET, respectively). PCr /ATP ratios significantly decreased during both treatment times in the β-GPA fed mice compared to control mice. Body and muscle mass significantly decreased after β-GPA treatment compared to controls, and BMR was significantly increased in β-GPA fed mice. NET significantly decreased in the 2-week treatment, but was not significantly different in the 6-week treatment. HET significantly decreased in the 2-week treatment, but in contrast to NET, significantly increased in the 6-week treated mice compared to control mice. We conclude that β-GPA induces a cellular energetic response that is similar to that of chronic hypoxia, and this change is a proximal cause of the enhanced exercise tolerance under hypoxic conditions.

25.8 ROSS, DL*; SHUBIN, NH; Univ of Chicago; *DarcyLRoss@uchicago.edu*

The Developmental Origins of Diversity: Shell Patterning in a Slipper-Shell Snail

Gastropods exhibit enormous extant diversity and have a rich fossil record, making them fertile ground for testing evolutionary theories. The regular coiling of the gastropod shell has made it a tractable shape to quantify, but some questions raised aren't answerable by morphology alone. What determines occupied morphospace (shapes of shells seen) compared to all possible morphospace? Why has the macroevolutionary shift from coiled shells to limpet-like shells occurred so often, when the reverse is so rare? Advances in genomics, developmental techniques, transgenics, mathematical modeling, and microCT scanning can be used with non-traditional model systems to crack open these old issues. ***Crepidula fornicata***, the slipper-shell snail, is a model caenogastropod that has been instrumental in our understanding of spiral cleavage, but the majority of its molecular resources extend only through early morphogenesis (largely pre-shell stages). Potential shell patterning genes, including well-conserved *Hox* genes and signaling molecules, cannot be found in existing caenogastropod transcriptomes, which holds back our understanding of shell development and evolution. To facilitate the study of shell patterning and the developmental basis of shell shape, we used Illumina HiSeq technology to sequence the transcriptome of pre-metamorphosis *Crepidula* larval stages from early shell secretion, two post-metamorphosis shell stages, and the mantle edge (shell secreting organ) of adult *Crepidula*. Our transcriptome and subsequent *in situ* hybridization revealed that some putative shell patterning genes are expressed at the right time and place to be participating in shell development, for instance the signaling molecule *dpp* is asymmetrically expressed in the direction of shell coiling in the shell gland. Preliminary functional assessments of the roles of these genes will be reported, including the phenotypic effects of inhibiting *dpp* activity, which produced a more straightened shell phenotype.

13.4 ROSTON, RA*; YAMATO, M; ROTH, VL; Duke University, National Museum of Natural History, Smithsonian Institution; *rachel.roston@duke.edu*

Bone overlap (telescoping) and the role of the basicranium in reorientation of the nasal passage in cetacean skulls

The facial skeletons of extant adult cetaceans (whales, dolphins, porpoises) are highly divergent from those of other mammals. Their divergence is due, in part, to the posterodorsal position of the external nares (blowhole) and to braincase "telescoping," an extraordinarily high degree of overlap between skull bones (Miller 1923). The arrangements of these features differ markedly among the two major sub-clades: toothed whales (odontocetes) and baleen whales (mysticetes). Detailed descriptions exist of adult morphologies, but the prenatal ontogeny that produces these morphologies is only minimally described. Here we investigate ontogenetic changes in orientation of several cranial features and growth of the bony elements associated with telescoping. We measured these changes from CT scans of fetal series of a dolphin species (*Stenella attenuata*) and the fin whale (*Balaenoptera physalus*) from the NMNH collection. Our data suggest that changes to the ventral skull are at the core of nasal passage reorientation, suggesting that the evolutionary changes to the face actually involve changes in relative growth to posterior regions of the skull. We also found that the overlapping of bones associated with telescoping develops progressively during the fetal period.

44.7 ROSVALL , KA*; BUECHLEIN, A; PETERSON, MP; GEORGE, EM; TANG, H; RUSCH, D; KETTERSON, ED; Indiana University; *krosvall@indiana.edu*

Transcriptional mechanisms linking prior social challenges and future phenotype

Understanding how animals are affected by their social environment is a major focus in organismal biology. For example, social challenges are thought to adaptively prepare animals for future social instability, but it is not clear whether and how this process occurs at the genomic level across the diversity of tissues involved in behavioral responses. We experimentally manipulated the social environment for free-living male dark-eyed juncos (*Junco hyemalis*), and we compared acute challenged males, persistently challenged males, and unmanipulated controls in patterns of genome-wide gene expression. With these data, we characterized socially sensitive gene networks and the hubs that coordinate responses within and among 11 tissues from the brain and body. We found that social challenges had both immediate and long-lasting effects on aggressive behavior, and induced widespread genomic shifts away from self-maintenance processes in the brain and body (e.g. immune function), while enhancing expression of spermatogenesis-related genes in the testes. Network analyses show that these changes were coordinated by tissue-specific synthesis and processing of neurotransmitters, not by systemic changes in testosterone, as is often thought to be the case. These results not only demonstrate how genomic changes throughout the brain and body contribute to organismal plasticity, but they also shed light on the complex interplay among tissues that together prime an animal for social instability.

136.4 ROTH, E*; SPONBERG, S; DANIEL, T; Univ. of Washington, Georgia Tech; *eatai@uw.edu*

Robustness Via Redundancy: Multisensory Control of Flight in Hawkmoths

Animals rely on information pooled across multiple sensory modalities to control locomotion. In effect, sensory feedback in behavior comprises numerous parallel feedback loops, collectively shaping the behavioral response. We show how these parallel pathways provide robustness via redundancy. These attributes, while beneficial to behavior, present experimental and analytical confounds in identifying the contributions of individual sensory pathways. Addressing this challenge, we present a novel experimental paradigm leveraging sensory conflict for the study of multisensory behaviors in animals. In this approach, animals are presented concurrent and uncorrelated stimuli across different modalities. In contrast to prevailing approaches, in which sensory pathways are isolated by means of inhibition or ablation, sensory conflict maintains the sensory machinery intact; a control theoretic analysis disentangles the contributions of sensory pathways from the ensemble. To demonstrate this paradigm, we examine the joint visual and mechanosensory control of flight in the hawkmoth. In the laboratory, freely flying moths feed from two-part, robotically actuated flowers. This allows independent control of the visual and mechanosensory (via proboscis) cues by motion of the flower facade and nectar spur respectively. As the flower moves side-to-side, moths follow to maintain their relative position. Empirical models (fit to input—output tracking data from an assay of sensory conflict conditions) suggest that each pathway alone would be sufficient to mediate behavior. As such, the pathways insure against damage or inhibition of the other. Extrapolating these models, we predict the behavioral response to a set of sensory isolation experiments (technically infeasible), and demonstrate that these experiments do not reliably reflect the contributions of parallel pathways.

59.3 ROTT, KH*; CAVIEDES-VIDAL, E; KARASOV, WH; University of Wisconsin, Madison, Universidad Nacional de San Luis & CONICET, Argentina; *krott@wisc.edu*

Activity of intestinal enzymes responds to multiple dietary signals in birds

Working previously with house sparrow (HOSP; *Passer domesticus*) nestlings near fledging, we found that (1) dietary carbohydrate induces intestinal disaccharidase activity, (2) dietary lipid depresses disaccharidase activity, and (3) aminopeptidase-N activity may be induced by increasing dietary protein. In the current study, we tested younger HOSP nestlings and also a non-passerine - Northern bobwhite (NOBO; *Colinus virginianus*) chicks - to see if the previously observed responses to multiple dietary signals were common among avian species. In order to disentangle the effects of varying substrate levels, three diets were used: one high in carbohydrate (HC), one high in protein (HP), and one high in lipid (HL). Maltase, sucrase, and aminopeptidase-N activities were determined in birds fed these diets, and ratios of maltase activity to aminopeptidase-N activity (M/A ratios) were then calculated. The M/A ratio tests for specific enzymatic responses to differing levels of substrates and can reflect tradeoffs in enzymes that might occur if intestinal apical membrane space is limiting. We found that lipid depressed carbohydrase activity in both avian species, and aminopeptidase-N activity was significantly higher in HOSP nestlings and NOBO chicks that had been fed the HP diet. M/A ratio was highest in birds fed the HC diet, although the ratio was highest in HOSP fed the HC diet due to enzymatic induction per gram of intestinal tissue, while the ratio was highest in bobwhites fed the HC diet mainly due to larger intestines. Overall, the enzymes studied responded to multiple dietary signals, and, for the most part, the patterns of response were similar. Funded by NSF IOS-1354893 to WHK & UNSL/CONICET to EC-V.

6.4 ROUSE, GW*; CARVAJAL, JI; OJI, T; MESSING, CM; Scripps Insitution of Oceanography, Nagoya University, Nova Southeastern University; *grouse@ucsd.edu*

Insights into Extant Crinoid Phylogeny from Transcriptomes and Targeted Capture Molecular Sequence Data.

Although the status of Crinoidea (sea lilies and featherstars) as sister group to all other living echinoderms is unquestioned, our understanding of relationships among extant crinoids is poorly understood. Recent molecular phylogenetic analyses of crinoids have revealed that major taxonomic revision is required. DNA sequence data for several hundred crinoid species corroborates the hypothesis that the stalked crinoid groups Bourgueticrinina and Guillecrinina are nested among the featherstars (Comatulida). Also, the placement of enigmatic crinoid genera such as *Cyathidium* and *Atopocrinus* has been assessed with such sequence data for the first time, and problematic major taxonomic issues within Comatulida are highlighted. Unfortunately, these results show little support for any of the competing hypotheses for the relationships among the major crinoid clades. An analysis of available transcriptomes for 15 crinoids, which span the extant diversity of the group, has allowed such an assessment. From this transcriptome data we have also used a targeted gene-capture approach and next generation sequencing for several hundred loci from more than 60 other crinoids. The methods are outlined and results are reported.

P2.183 ROWSEY, LE*; KHURSIGARA, AJ; ESBAUGH, AJ; Univ. of Texas, Marine Science Institute ; *lauren.rowsey@gmail.com*

Effects of Sub-Lethal Oil Exposure on Predator-Prey Dynamics in a Larval Marine Fish

The *Deepwater Horizon (DWH)* oil spill led to the exposure of many commercially and ecologically important species to crude oil at early life stages. This oil contains toxic polycyclic aromatic hydrocarbons (PAHs), and exposure has been shown to result in lethal and sub-lethal effects. In particular, sub-lethal exposure is known to result in substantial cardiac impairment, which may have ecological consequences related to reduced oxygen supply capacity and exercise performance. This study therefore sought to explore the impacts of sub-lethal oil exposure on the prey capture ability of early life stage red drum (*S. ocellatus*) using two test designs. The first test used an open field routine activity assay as an indirect measure of foraging behavior, while the second test directly measured prey capture ability. In both cases fish were exposed to oil via water accommodated fractions for a 24 h period prior to testing. Larvae (21 dpf) exposed to 56 μg/L ΣPAH exhibited a lower total swim distance in the open field activity tests, which is consistent with the hypothesis that cardiac impairment would reduce foraging potential. Similarly, prey capture assays revealed a dose dependent decline in captured food items by exposed larvae (35 dpf), with a significant 3-fold decrease in captured items observed at 56 μg/L ΣPAH. This was coincident with a significant increased time to first and fifth capture. Overall, these data support the hypothesis that the cardiac impairment resulting from oil exposure in early life can result in deleterious performance indices, such as the ability to find and capture prey.

S9.2 RUBENSTEIN, DR; Columbia University;
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From individual to group-level variation in cooperative behaviors and complex societies

Attempts to study the developmental and proximate mechanisms underlying social behavior in animals have emphasized a series of proximate pathways that influence individual traits such as pro- and anti-social behaviors. However, to understand the mechanistic bases of more complex cooperative behaviors like the formation of societies, we must also consider how these individual traits can influence the traits of the social group, such as dominance rank and reproductive structure. Using examples from three diverse cooperative systems—birds, insects and crustaceans—I will develop a framework for linking mechanism with both individual and group-level traits. First, I will discuss how early life conditions influence fitness later in life in cooperatively breeding starlings living in an unpredictable environment in Africa. I will show how among-year variation in rainfall is related to DNA methylation in the regulatory region of the glucocorticoid receptor during development and the likelihood of breeding in adulthood. Next, I will discuss how environmental conditions and the likelihood of interspecific competition interact to influence within-species variation in cooperative behavior at the level of the group in burying beetles sampled along an ecological gradient in Taiwan. Finally, I will detail how different forms of social organization in eusocial snapping shrimp represent alternative evolutionary trajectories and discuss how individual pro-social behaviors may influence these patterns. By contrasting the approaches that researchers often take in vertebrate and invertebrate study systems, I will argue that we need to consider both individual and group-level variation in social traits and social structure if we are to understand the mechanistic bases of complex social behaviors in animals.

P1.246 RUBIN, AM*; DIAMOND, KM; SCHOENFUSS, HL; BLOB, RW; Clemson Univ, St Cloud State Univ;
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Assessing the impacts of environmental contaminants on escape behavior in the migratory stream goby Sicyopterus stimpsoni

Environmental contaminants such as agricultural runoff and pharmaceutical pollutants in freshwater systems have been shown to alter fish behavior. Such effects may be especially critical for prey fishes, as they could impact performance during behaviors necessary for survival, such as detection and escape from predators. We tested for effects of environmental contaminants on escape performance in juveniles of the Hawaiian freshwater goby *Sicyopterus stimpsoni*, a species that must migrate through predator-dense stream reaches on its way to predator-free adult habitats, but which is facing increasing risk of contaminant exposure in the downstream waters through which it migrates. We exposed juvenile *S. stimpsoni* to a combination of common pharmaceutical (sulfamethoxazole, methocarbamol, diclofenac, temazepam) and agricultural (alkylphenol mixture, estrone, triclosan) pollutants for five days at three concentrations representing a realistic environmental gradient of exposure. After exposure, the ability of surviving fish to produce an escape response was measured in an arena by applying a water-jet stimulus and filming with high-speed video. Trials were analyzed to determine how frequency of response, duration of response, and escape angle were affected by different concentrations of contaminants. Our analysis showed that while survivorship differed between treatments, with lower survival at higher concentrations, there was only a limited effect of contaminant exposure on escape performance. These results suggest that the impacts of contaminants on survivorship in this species are more likely to be direct than to be mediated through the ability to execute critical behaviors.

23.5 RUBIN, L.B*; SMITH, K; University of Louisiana at Lafayette;
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Inactivation of fgfr1 and fgfr2 in Postnatal Astrocytes

Fibroblast growth factors (Fgfs) are a family of 22 cytokines that bind to 4 receptors, many of which play a critical role in cortical development. Fgf ligands, including Fgf2, and the Fgfr1 and Fgfr2 receptors are expressed by astrocytes and astrocytic stem cell lineages of the developing and adult CNS. Previous studies have shown that Fgfrs can have compensatory effects on proliferation and development. We have inactivated Fgfr1 and Fgfr2 in postnatal astrocytes by tamoxifen inducible Cre mediated recombination using the hGFAP-CreERT2 (GCE) transgene. We targeted postnatal astrocytes by administering injections of tamoxifen from P14-17, 60 mg/kg i.p. We tested locomotor behavior of the mice for 30 minutes in an open field. Male double KO mice showed hypoactivity compared to male control littermates with total time immobile having a p-value of .0380. Other trends were less distance travelled (p=.0542), lower mean speed (.0567), and more total mobile episodes (0521) possibly indicating that the animals began more movements but were slower and spent more time resting. We observed no differences in anxiety behaviors on the elevated plus maze test, and no differences in memory were observed in the 1-day morris water maze. It was previously shown that Fgfr1 and Fgfr2 double KO starting at E13.5 lead to multiple cerebellar abnormalities. The locomotor behavior findings lead us to hypothesize that there may be a postnatal cerebellar defect in Fgfr1/Fgfr2 double KO mice. We compared control and Fgfr1/Fgfr2 double KO mice on a hindlimb clasping test. We found double KO mice had significantly higher scores on this test (p=.05), indicating an impairment in motor coordination. Future work will examine cerebellar morphology. We will compare the effects of Fgfr1 single and Fgfr1/Fgfr2 double mutants upon PV neuron maturation, and postnatal hippocampal proliferation.

P3.155 RUFFIN, TC*; KOOPMAN, HN; NEUROHR, JM; CALIRI, AW; KINSEY, ST; Univ. of North Carolina Wilmington, Wilmington; *tcr9304@uncw.edu*

The relationship between standard metabolic rate and lipid content in fishes

Previous research has shown that skeletal muscle fibers often grow to the brink of oxygen diffusion limitation. This increase in fiber size leads to a reduction in energy consumption devoted to maintaining the membrane potential across the sarcolemma in resting muscle, since large fibers have a lower surface area to volume than small fibers. For this study we proposed that whole animal resting metabolic rate would be related to the total membrane area of the animal. We hypothesized that the standard metabolic rate in a number of fishes would be positively correlated to membrane lipid content, but unrelated to non-membrane lipid content. Metabolic rate was assessed using closed chamber respirometry, and lipid content was then assessed using thin layer chromatography. The oxygen consumption rate scaled negatively with body mass across all species. Six lipid classes were characterized: triacylglcerols (TAGs), free fatty acids (FFAs), sterol esters, cholesterol, and two classes of phospholipids, and all scaled negatively with body mass. As expected, standard metabolic rate was positively correlated with membrane lipids, and not with TAGs. These results suggest that the degree of metabolic compartmentalization has a significant impact on variation in standard metabolic rate.

4.3 RUMMEL, AD*; SWARTZ, SM; MARSH, RL; Brown University; *andrea_rummel@brown.edu*

Contractile Properties of a Carpal Extensor in Carollia: Are Wing Muscles Adapted to Operate Below Core Body Temperature?

Bat wings possess a large number of joints that are controlled relatively independently by muscles within the wing. Previous studies have shown that the temperature of bat wings is lower than that of the body during flight with the distal wing approaching air temperature. Bats are also known to use daily torpor and may initiate flight with reduced body temperatures (T_b). Muscle mechanical performance declines with temperature; thus, low muscle temperature (T_m) could potentially influence flight performance. The bat extensor carpi radialis longus (ECRL) is a forearm extensor that is critical to extending the wings and keeping them open during downstroke. Because this distal wing muscle likely operates at a T_m less than T_b, we predicted that the performance of the bat ECRL would be less temperature dependent than that of other vertebrate skeletal muscles. We measured in vitro the isometric and isotonic contractile properties of the ECRL in *Carollia perspicillata*, from 22 to 37 °C at 5 °C intervals. The Q_{10}'s for shortening velocity were approximately 1.2, 1.4, and 2.0 for the temperature ranges of 32 - 37, 27 - 32, and 22 - 27 °C, respectively. Similarly, the ½ relaxation time from a tetanus had Q_{10}'s of approximately 1.3, 1.4, and 1.9 for the same temperature intervals. By comparison, in the limb muscles of other mammals, the Q_{10}'s reported for Vmax are approximately 1.8 between 25 and 35 °C, and the Q_{10}'s for relaxation times are greater than 2.0 over this temperature range. These findings suggest that the wing muscles in bats may be adapted to maintain function across a wider range of temperatures than are limb muscles from other mammals.

138.7 RUPP, AR*; SEVER, DM; Univ. of Louisiana, Lafayette, Southeastern Louisiana Univ.; *aer0838@louisiana.edu*

Histology and Ultrastructure of Mental Glands and Caudal Courtship Glands in Three Genera of Plethodontid Salamanders

Salamanders in the family Plethodontidae exhibit a unique tail-straddle walk during courtship that can include the use of sexually dimorphic mental glands and caudal courtship glands. Mental glands are found in the skin of the lower jaw and caudal courtship glands are found in the skin of the dorsal base of the tail in some male plethodontids, and both glands are thought to increase female receptivity during courtship. While many histological studies of mental glands have observed intergeneric morphological variation, only four light microscopy studies of caudal courtship glands exist and there are even fewer ultrastructural studies for both types of glands. This study hypothesized that similar intergeneric morphological variation would be seen in caudal courtship glands as had already been seen in mental glands, and that glands would hypertrophy during the breeding season. Males and females from three genera, *Plethodon*, *Eurycea*, and *Desmognathus*, were collected throughout the year, focusing on species that were previously unstudied for caudal courtship glands. Tissues from the chin and the dorsal base of the tail, in both males and females, were taken from each collected individual and analyzed using either light or electron microscopy. Results show that there is intergeneric morphological and seasonal variation of mental and caudal courtship glands in these genera. These data represent the first use of scanning electron microscopy to study morphological variation of these glands, as well as the first histological data on caudal courtship glands in these species. These data suggest the need for further investigation of caudal courtship glands to better understand the evolution of the tail straddle walk in this family.

45.4 RUSCH, TW*; ANGILLETTA, MJ; Arizona State University; *trusch@asu.edu*

Competition for Thermal Resources between Male Lizards Altered Thermoregulatory Behavior and Hormone Levels

Every organism must thermoregulate to maximize its performance, but competing organisms limit access to preferred microclimates. Such competition creates hierarchies in which dominant individuals have more access to thermal resources than subordinate individuals, thus creating disproportionate costs of thermoregulation. To assess the costs of competition, we measured the body temperatures, activity levels, and hormone concentrations of male lizards (*Sceloporus jarrovi*) in a thermal arena, when alone and when paired with a smaller or larger lizard. Competition caused large males to use the heat source more often, resulting in body temperatures above the preferred temperature range. Conversely, small males spent less time near the heat source and permitted body temperatures to regularly fall below their preferred temperature range. Competition caused both large and small males to circulate more corticosterone, although this effect was more pronounced in small males. Similarly, competition caused large males to circulate more testosterone, while small males circulated less testosterone. Both dominant and subordinate males paid costs of competition for thermal resources, including poorer thermoregulatory performance and greater physiological stress. Thus, competition for thermal resources should feature more prominently in ecological and evolutionary models of thermoregulation.

P1.59 RUSCH, TW*; ANGILLETTA, MJ; Arizona State University; *trusch@asu.edu*

Locomotor Capacity and Social Context under Perceived Predation Threat in Male Lizards

Locomotor capacities may constrain antipredator decisions and hence have important ecological and evolutionary consequences. However, the social context may buffer antipredator responses as an increase in prey group size reduces the amount of risk per individual. Thus, we studied the effects of both locomotor capacity and social context of male lizards (*Sceloporus jarrovi*) on antipredator behavior in laboratory arenas. First, we measured individual locomotor capacities in the form of maximal sprint speed at 7 different temperatures. Then, pairs of size-matched lizards were assigned to one of two treatment orders; 1) isolated then paired, or 2) paired then isolated. Predation risk was simulated by the researcher approaching the arena and chasing each lizard into a single shelter within the arena. We predicted that faster and paired lizards would exhibit reduced antipredator behaviors. We will report the interactive effects between locomotor capacity and social context on escape behavior and reemergence times under repeated artificial predator attacks.

34.1 RUSSELL, A/L*; BUCHMANN, S/L; PAPAJ, D/R; University of Arizona; *averyrussell@email.arizona.edu*
No Experience? Not a Problem: Flexible Pollen Foraging by Bees Does Not Require Learning
Bees foraging for floral rewards are one of our most thoroughly studied examples of generalist foraging ecology. Nectar-foraging generalist bees forage effectively from diverse plant species by modifying their collection behavior via learning. While generalist bees must also collect pollen from diverse plant species, surprisingly no literature has examined whether and how generalists are able to adjust their behavior to collect pollen effectively. Most generalist bees, such as bumblebees, use two routines to collect pollen from diverse floral morphologies. Bees scrabble for pollen when pollen is presented openly on the anthers; to collect pollen from flowers that conceal it within tubal floral morphology (poricidal floral morphology), bees sonicate. We demonstrate that bumblebees exhibit flexible and effective pollen collection by switching between their two pollen collection routines, floral sonication and scrabbling. Flexibility is regulated by the interplay between two floral cues: chemical anther cues stimulating sonication and mechanical pollen cues suppressing it. We discuss how this flexibility differs in key respects from that of nectar foraging and how it could have facilitated the repeated evolution of poricidal floral morphology.

P3.232 RUSSO, KA*; BYRNES, G; Siena College; *gbyrnes@siena.edu*
The role of arm-swing while running over uneven terrain
Arm-swing during running aids to counteract the torque associated with leg oscillation. The benefits of arm-swing during running on even surfaces are well established and include energy minimization and balance. In addition, arm movements are used to maintain balance during asymmetric movements. The "roughness" of a surface likely influences both the energy required to run and the requirements to maintain balance. However, we know little about how arm-swing is modulated while running over uneven terrain. Therefore, the goal of the proposed project is to understand the role of arm-swing during running over uneven terrain. Runners were fitted with two small inertial sensors attached to the torso and hips to measure footfall and shoulder and hip rotations. Subjects were filmed while running over an approximately 25m course consisting of smooth, uneven, and smooth sections to examine differences in arm-swing. Preliminary results show that both the magnitude of shoulder rotation and the phase of shoulder rotation with respect to hip rotation is more variable when running over uneven compared to smooth terrain. This suggests that arm swing contributes to stability while running over uneven terrain.

139.1 RUUSKANEN, S*; GROOTHUIS, TGG; DARRAS, VM; GIENAPP, P; SCHAPER, SV; VISSER, ME; Unive of Turku, Finland; Dept of Animal Ecology, Netherlands Institute of Ecology (NIOO-KNAW), , Groningen Institute for Evolutionary Life Sciences, Univ of Groningen, The Netherlands, Laboratory of Comparative Endocrinology, KU Leuven, Belgium, Dept of Animal Ecology, Netherlands Institute of Ecology (NIOO-KNAW); *skruus@utu.fi*
Egg Thyroid Hormones: An Unexplored Mechanism for Maternal Effects in Birds
Maternal effects are a powerful way to influence offspring phenotype and fitness, thus strong selection is expected. Although data from other vertebrates suggests a prominent role for maternal thyroid hormones (TH) on offspring development and survival, the causes and consequences of variation in avian maternally-derived THs (via eggs) have been largely neglected. We studied environmental variation in egg TH levels (thyroxine, T4 and triiodothyronine, T3) in wild great tits (*Parus major*) and its heritability in captive-bred siblings of wild origin. We experimentally elevated egg TH levels in a wild population to study the effects on fitness-related traits. Yolk T4 (but not T3) concentration was correlated negatively with temperature, positively with timing of breeding and increased with laying order within clutches. Interestingly, T3 (but not T4), was heritable ($h2 = 0.25$). Experimental egg TH elevation showed a sex-specific effect on offspring growth: it increased the growth of male nestlings, but decreased growth in female nestlings, relative to controls. Egg TH elevation had no effect on behavior, metabolic rate, hatching and fledging success. These studies demonstrate, for the first time in a wild bird species, the biological relevance of variation in maternal thyroid hormones in egg yolk on offspring development, and open a new, interesting avenue for further research in the field of hormone-mediated maternal effects.

P3.203 RZUCIDLO, C/L*; MORAN, C/J; GERRY, S/P; Fairfield University; *caroline.rzucidlo@student.fairfield.edu*
Taking Functional Morphology to the Field: Do Bluegill Feed Differently in the Wild Versus the Lab?
A natural gap in knowledge is created when scientists make inferences about animals in the wild by conducting experiments on captive animals. This gap is created by imposing limits to animal behaviors that are not experienced in the wild. We sought to bridge this gap by filming polyphenic bluegill feeding in the wild. Given the restrictions of lab aquaria, we hypothesized that wild fish will use more ram during feeding than captive fish. Additionally, we hypothesized that the differences in feeding behaviors that we observed in the lab between ecomorphs (littoral and pelagic) will be observed in the wild. To address these hypotheses we fed fish in the view of a GoPro camera array, which allowed us to film feeding events in 3D. We found that wild fish produced a significantly larger relative gape while using more ram to capture their prey. Additionally, wild fish displayed a faster gape velocity than fish filmed in the lab. Previous research in the lab has shown that littoral bluegills use more ram than pelagic bluegills during feeding. This relationship was also seen in wild feeding events with littoral fish using more than double the amount of ram than pelagic fish. With this study we highlighted some of the constraints imposed on fish when bringing them to the lab for experimentation. Additionally, we showed that pelagic and littoral fish feed differently as was seen in lab experiments.

P2.23 SALAS, H.K.*; GUNDERSON, A.R.; SAYAVONG, N.; STILLMAN, J.H.; TSUKIMURA, B.; California State University, Fresno, Romberg Tiburon Center, CA; *hazz332@mail.fresnostate.edu*

Effects of Thermal Stress on Vitellogenin Levels in the Hemolymph of the Anomuran Crab Petrolisthes cinctipes

Intertidal organisms, such as the porcelain crab, *Petrolisthes cinctipes*, are faced with rising temperature extremes that may interfere with their physiological performances. *P. cinctipes* inhabits the upper-mid intertidal zone and is regularly exposed during low tides. Increased abiotic stressors interfere with many aspects of this organisms' physiology, including reproduction. Reproductive activity can be measured through the quantification of the yolk protein vitellogenin (Vg), found in hemolymph. Our development of an ELISA for *P. cinctipes* has allowed for quantification of hemolymph levels of Vg. Monthly observations indicated *P. cinctipes* up-regulate their Vg production during new moon periods and were depressed by the new moon. In addition, Vg sampling of *P. cinctipes* revealed that Vg levels are higher in fall and winter months, and low throughout early spring and summer. Decreased reproduction during summer months may be affected by temperature, day lengths, or both. To examine these factors, *P. cinctipes*, collected in both winter and summer months, were sampled for hemolymph Vg. Individuals were then divided into four treatments to test the effects of day length and temperature. After a two week exposure, another hemolymph sample was drawn. Both samples were analyzed by ELISA. Crabs exposed to thermal stressors from winter months had depressed levels of Vg, and crabs from summer months had sustained low levels of Vg. Day length appeared to have a lesser affect on Vg levels. This project is supported by NSF grant #1451423 to BT and JS.

P1.56 SALAZAR-NICHOLLS, MJ*; ESCOBAR, KD; WARKENTIN, KM; Pontificia Universidad Católica, Ecuador, Western Connecticut State University, Boston University; *majonicholls2909@gmail.com*

Development of hatching ability in red-eyed treefrogs: escape from complications.

Hatching early allows embryos to escape threats to eggs, but increases risks to larvae. Red-eyed treefrogs hatch by rapidly releasing enzymes to digest a small hole in their membrane, then squeezing out aided by turgor pressure. Displacement from the initial hole can occur spontaneously and in predator attacks, complicating hatching by capsular collapse as fluid escapes. To assess developmental changes in ability to recover from such complications, we manually displaced 3-5 day old embryos during hatching, interrupting exit through their initial hole, and recorded macro-video. To induce hatching of younger, vibration-insensitive embryos, we submerged individual eggs in hypoxic water. For older embryos, we used a blunt probe to jiggle eggs within clutches. Once an embryo began hatching, we manually displaced it, moving its snout away from the forming or just-formed hole. We analyzed videos to assess if and how embryos escaped. The least-developed embryos rarely escaped from collapsed capsules but performance improved rapidly; late stages always escaped. Embryos escaped by either re-finding their first hole or making a second. The post-displacement delay to start an exit through the first hole was similar across stages. Even at the earliest stages, a few individuals made second holes, but the likelihood of doing so increased rapidly, to about 75%. More developed embryos spent less effort searching for their first hole; they made second holes sooner and more efficiently. They also passed through the membrane more rapidly, with less body compression in transit. Along with high risk after hatching, poor ability to escape from hatching complications may select against unnecessary hatching attempts at early developmental stages.

64.6 SALCEDO, MK*; HOFFMAN, J; COMBES, SA; MAHADEVAN, L; Harvard University, UC Davis; *maryksalcedo@fas.harvard.edu*

Wing vein networks across insect orders: examining hierarchical network structure and hemolymph flow

An insect wing contains a series of vein networks that transport hemolymph. Fluid transport in the wing is necessary for wing inflation during metamorphosis, cell growth, thermoregulation during basking, and maintenance of neural connections. Despite the importance of fluid flow in insect wing veins, the physics mediating this flow, and its overall direction and velocity remain largely unknown. We explored the hemodynamics of insect wing veins on two fronts, one theoretical and one experimental. We first used a network analysis approach to understand how wing network patterns and hierarchies emerge across phylogenetic orders. Using Python-based segmentation analysis and network Generalized Erdos Numbers code, we examined wing networks across 95 individuals spanning 13 insect orders. The metric of Generalized Erdos Numbers is based on a geometric flow term, $radius^4/length$ (where radius is the width of the wing vein and length is the distance between nodes), which is related to the resistance to flow. This naturally leads to examining hemolymph flow across a wing. The second part of this project focused on observing and measuring flow within the wings of live Orthopterans (Family: Acrididae, Gryllidae). These animals were chosen for their "loopy" networks in the forewing and lattice networks in the hindwings. By using the analyzed networks as predictors of flow hierarchy, we then perturbed these networks experimentally in vivo in order to observe how the hemodynamics change. These novel approaches provide insight into morphological diversity seen in flying insects.

28.4 SALEM, H*; KALTENPOTH, M; Emory University, MPI for Chemical Ecology; *hssalem@emory.edu*

Nutritional endosymbionts mediate folivory in leaf beetles

Like many herbivores, leaf beetles (Coleoptera: Chrysomelidae) depend on a range of plant cell wall-degrading enzymes to break down ingested material for nourishment and development. Here, we highlight the role of an obligate endosymbiont in mediating this process in the leaf beetle Cassida rubiginosa. Our survey of the bacterial community associated with C. rubiginosa revealed a universal partnership with a γ-proteobacterial species, one that phylogenetically clusters alongside other nutritional mutualists of insects, including Buchnera (aphids) and Blochmannia (ants). Fluorescence in situ hybridization (FISH) revealed symbiont localization to be restricted to a pair of sac-like organs connected to the foregut, as well as, in females, a pair of accessory glands associated with the ovipositor. Symbiont vertical transmission is accomplished through the singular topping of a "caplet" on the exterior surface of each egg. Piercing the egg caplet disrupts the transmission cycle, resulting in symbiont-free beetles that suffer retarded growth and higher mortality. Genome sequencing revealed that the symbiont possesses a drastically reduced genome (257,000 bp). However, unlike its close γ-proteobacterial relatives, C. rubiginosa's mutualist lacks all the necessary genes to synthesize essential amino acids or vitamins. Instead, we discovered genes involved in the synthesis and export of pectinase, an enzyme catalyzing the breakdown of pectin. Comparative transcriptomic analysis across different regions of the insect's body revealed pectinase expression to be restricted to the symbiotic organs. Consistent with our expectation that the symbionts contribute towards host fitness by mediating the breakdown of pectin, agarose diffusion assays using protein extracts from the symbiotic organs revealed strong pectinolytic activity.

135.2 SALIN, K*; AUER, SK; ANDERSON, G; VILLASEVIL, EM; SELMAN, C; METCALFE, NB; SALIN, Karine; University of Glasgow, UK; *karine.salin@glasgow.ac.uk*

How Does Mitochondrial Functioning Constrain Energy Efficiency?

Although a great number of ecophysiological studies have focused on factors affecting energy acquisition and allocation, surprisingly few have considered energy processes at the mitochondrial level. Energy derived from the diet becomes usable only after being oxidized and converted into adenosine triphosphate (ATP) by the mitochondria. Here we illustrate the role of intraspecific variation in mitochondrial functioning in constraining animal energetics using evidence from an ectotherm, the brown trout *Salma trutta*. We show that conspecifics living in the same environment displayed up to a 3-fold variation in the rate of energy dissipation through mitochondrial proton leak respiration. Those that had a greater mitochondrial leak respiration may be to partially offset this leak, as revealed by a higher whole-organism metabolic rate. These individuals also had the poorest performance at high ambient high temperatures. However, it is important to note that mitochondrial properties are not fixed but change according to conditions: fasting caused disproportionate changes in mitochondrial capacities of the liver, such that substrate oxidation increased far more than did the ATP synthesis. As a result, the ATP/O ratio (the amount of ATP produced per unit of oxygen consumed, i.e. the efficiency of ATP production) decreased in response to fasting. These illustrations, combined with examples from the literature, suggest that mitochondria can be a significant constraint in the use of energy resources and their allocation into ATP. Among-individual variation in mitochondrial functioning is therefore likely to contribute to the proximate causes of differences in animal performance.

47.7 SALINAS-SAAVEDRA, M*; MARTINDALE, MQ; Whitney Marine Lab, University of Florida, Florida; *mssaavedra@whitney.ufl.edu*

Understanding animal Cell polarity: Insights from early embryogenesis of the ctenophore Mnemiopsis leidyi.

Par proteins are conserved components of cellular polarization during early embryogenesis and their role in establishing embryonic asymmetry have been widely studied in bilaterianS. In embryos of the cnidarian *Nematostella vectensis* the components of the Par system (NvPar-1, NvPar-3, NvPar-6, NvaPKC, and NvLgl) distribute throughout the microtubule cytoskeleton of pre-blastula stages without any clear polarization along any embryonic axis. However, they become asymmetrically localized at later stages, when the embryo forms an ectodermal epithelial layer in a manner seen in bilaterian animals: NvLgl and NvPar-1 localize in the basolateral cortex, and NvaPKC, NvPar-6, and NvPar-3 at the apical zone of the cell. Interestingly, *N. vectensis* shows a "random" cleavage pattern and it undergoes gastrulation at the animal (not vegetal) pole of the egg. In contrast, Ctenophores (which also gastrulate at the animal pole) develop under a highly stereotyped embryogenesis; begging the question of whether Par genes regulate the cleavage program and help specify the site of gastrulation. By immunohistochemistry and in vivo imaging of cytoskeletal components we characterized the cytology of blastomeres and epithelial cells during the early embryogenesis of the ctenophore *Mnemiopsis leidyi*. In addition, mRNA over expression of the components of the ctenophore Par system shows that these proteins distribute differently compared to what we have described for *N. vectensis* embryos. These observation were confirmed using cross reactive antibody staining. These data will provide a glimpse into the evolution of cell polarity in metazoan embryos.

S9.6 SALTZMAN, W.; University of California, Riverside; *saltzman@ucr.edu*

Paternal Behavior in a Biparental Rodent: Between- and Within-animal Variation

Although uniparental care of offspring is the rule among mammals, approximately 5% of species practice biparental care, in which both parents contribute to the rearing of their young. Males in some biparental species exhibit pronounced changes in their behavioral responses to infants during the transition to fatherhood. Such changes have been especially well studied in the monogamous, biparental California mouse (*Peromyscus californicus*). New fathers in this species undergo shifts in several neural, metabolic, morphological, and behavioral measures, which are likely mediated by hormonal changes occurring shortly before and after the birth of pups. For example, new fathers and nonbreeding males show differences in expression of hormone receptors and neuronal morphology within specific brain regions, as well as differences in body mass, organ masses, and behavioral responses to stressors. The stimuli eliciting such effects are not well understood but may include cohabitation with a female -- especially a pregnant female -- and exposure to pups. Paternal behavior can be modestly inhibited by acute exposure to stressors or stress-related hormones; however, exposure to chronic stressors does not markedly alter paternal care. At the level of inter-individual variation, few differences are seen among fathers, which consistently exhibit attraction and nurturance toward pups. Virgin males, in contrast, show pronounced differences in pup-directed behavior, ranging from caretaking to infanticide. The proximate bases of these differences are not clear, but previous exposure to pups enhances caretaking behavior in virgin males. Thus, variation in paternal responsiveness in California mice may result from both physiological and experiential factors. (Supported by NIH HD075021, NIH HD075021, and NSF IOS1256572.)

P1.86 SAMPLE, A*; VON DASSOW, YJ; VON DASSOW, M; Bowling Green State University, Ohio, Duke University Marine Lab, Beaufort, NC; *brutus.sample@gmail.com*

Egg mass clumping and exposure survival in intertidal gastropod embryos

Intertidal organisms use a variety of adaptations to protect offspring from environmental stresses such as desiccation and UV radiation. One adaptation is to attach offspring to safe benthic substrata, as seen in the intertidal sea slug *Haminoea vesicula* in False Bay, San Juan Island, USA. When preferred substrata are scarce, slugs often lay their ribbon-shaped egg masses in dense clumps, attached to one another instead of directly to the substratum. Clumping may have disadvantages: ribbons in the clump center may be oxygen-deprived, and clumps are frequently dislodged from their substrata by waves and currents, becoming prone to stranding at low tide. However, we hypothesized that stranded clumps provide a survival advantage over stranded single egg ribbons. Ribbons in the clump interior should be shielded from drying and UV exposure. We tested this idea with *H. vesicula* embryos that were midway through development, at a stage when they spin rapidly in their envelopes. We simulated low tide by exposing individual ribbons and artificial clumps to air and sun for 1 hr., during which we noted cessation of spinning (an indication of stress). Ribbons and clumps were then rehydrated in seawater for 24 hrs., after which survival rates were recorded. Embryos in individual ribbons stopped spinning sooner than embryos at the clump edge, but next-day survival did not differ significantly between these two groups, or between embryos in clump middles and edges. However, significantly more embryos survived in the clump middle than in individual ribbons. These data suggest that egg ribbon clumping can aid survival of embryos stranded at low tide. This may relieve some of the pressure on parents to find ideal laying circumstances.

9.8 SAMSON, J. E.*; MILLER, L. A.; UNC Chapel Hill;
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Using a Neuroscience Approach to Uncover Patterns of Collective Behavior in Pulsing Corals

Xeniid corals, a family of soft corals, display a unique behavior: individual polyps within a colony actively pulse, increasing the local water flux and thus mass transfer (i.e. nutrient and gas exchange). From observations in the lab and in the field, it seems that this individual pulsing behavior generates collective pulsing patterns on the colony scale. Since cnidarians (corals, jellyfish, anemones, and their relatives) lack a centralized nervous system or integration center, it is unclear how collective behavior arises within a colony. In this study, we examined whether recurring pulsing patterns could be observed and quantified within a small colony (i.e. whether the colony functions as a predictable network of polyps). Using a neuroscience approach to analyze our video data, we found repeated pulsing patterns when looking at four neighboring polyps within a colony. Several hypotheses can be proposed to explain the observed pulsing patterns: 1) the collective behavior is the result of random individual behavior, 2) the collective behavior follows a Markov model, 3) the individual polyps act as independent oscillators with set intrinsic pulsing frequencies, and 4) the individual polyps act as coupled oscillators. For each hypothesis, we built a model that we compared to the collected data. We had to reject all hypotheses but the fourth, meaning pulsing behavior in small coral colonies can be modeled using coupled oscillators, although it is still unclear what the coupling consists of (neural, chemical, external, etc.). Future research will delve further into this coupling mode. Additionally, We are investigating the potential benefits of this collective pulsing behavior on nutrient and gas exchange rates using computational fluid dynamic models.

P1.227 SANDE, LM*; ZHANG, C; POMETTO, S; BEARD, CE; APRELEV, P; ADLER, PH; KORNEV, KG; Clemson University;
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Role of Saliva on Galea Bending and Self-Repair of the Lepidopteran Proboscis

We have investigated and are exhibiting a methodology for studying the self-repair mechanism of the split lepidopteran proboscis in active and sedated butterflies. To probe the repair capabilities, we have separated the proboscis far from the head with a metal post of diameter comparable to the butterfly galea and moved the post ever closer to the head in increments of 500 microns until the proboscis was fully split. Once split, we brought the post back towards the tip in steps and observed the convergence of the two galeae back into one whole proboscis. To determine the materials properties of the proboscis, the process of galeae gathering was filmed with a high speed camera. The galea profile, extracted from the videos as a function of time, was then fitted with a mathematical model based on the Euler-Bernoulli beam theory where each galea was treated as a beam undergoing small deflections. The theory was augmented by introducing the bending moments modeling the muscular action as well as by a capillary force due to the saliva meniscus. Experiments on sedated butterflies, when the muscular action was diminished but saliva was present, show the crucial role of saliva meniscus in bringing galeae together. The model sheds light on the evolutionary development of the butterfly proboscis; in particular, the effect of the galea cross-section and anisotropy of materials properties.

14.2 SANDERS, EK*; DONATELLI, CM; TYTELL, ED; Tufts University; *erin.sanders@tufts.edu*

With every fiber: the effects of collagen fiber orientation on the body mechanics of six species of elongate fishes

Fish skin has many components that contribute to its protective, yet flexible structure. The dermis of fish skin is partially composed of highly ordered helical collagen fibers, which wrap around the body of the fish. Previous studies indicate that skin and scales have a significant effect on flexural bending stiffness and side-to-side swimming kinematics. However, when fishes swim, they also twist around their long axis, and little is known about how skin effects this torsional motion. In this study, we quantified the helical collagen fiber angles in the skin of six species of elongate fishes that twist their bodies by different amounts during swimming. We used trypsin to remove muscle and clear pigmentation of skin samples and used polarizing filters to image the fibers under a dissection microscope. From ventral to dorsal, one set of fibers points towards the anterior end and one set of fibers points towards the posterior end. Using the images, we measured the angle of the anterior and posterior pointing fibers compared to the position along the body. Understanding the effect that skin fibers have on torsional stiffness and overall body mechanics, and their relationship to swimming kinematics and lead to a greater understanding of fish swimming behavior in the natural environment.

S5.6 SANDERS, Jon G*; SONG, Se Jin; METCALF, Jessica; AMATO, Katherine; DELSUC, Frederic; MCKENZIE, Valerie; KNIGHT, Rob; University of California San Diego, Colorado State University , Northwestern University, University of Montpellier, University of Colorado Boulder; *jonsan@gmail.com*

The evolution of the tetrapod gut microbiome

In surveys of this planet's microbes, animal guts represent one of the major axes of diversity: communities in animal guts are as different from free-living communities as free-living communities are from one another. Probably not coincidentally, these hosts also evolve, themselves changing as a consequence of their external and internal environments. How do we best understand the diversity of host-associated microbes in light of the evolutionary history of their hosts? Despite tremendous recent investment in microbiome research, our ability to make comparative inferences about host-associated microbiomes commensurate with the scale of our knowledge of host evolution remains strongly constrained by available data. Here we present initial results from a novel dataset of vertebrate distal gut microbiota that expands on previous comparisons by an order of magnitude, comprising over 3000 samples from over 800 tetrapod species. Analysis of changes in microbial diversity both across the broader host phylogeny and in targeted regions of denser taxon sampling reveals the importance of host relationships in explaining patterns of microbial diversity, even with respect to major ecological changes such as host diet. We explore these changes both at the level of microbial community diversity, and, using recently developed statistical and computational techniques, at the level of individual microbial lineages. Finally, we discuss our comparative results in light of recent findings from experimental interventions in model and non-model organismal systems to propose a conceptual model for the coordinated evolution of animals and their gut microbiomes.

19.3 SANDMEIER, FC*; MALONEY, NK; TRACY, CR; HUNTER, K; DUPRE, S; Colorado State University-Pueblo, Vanderbilt Univesity, University of Nevada, Reno, University of Nevada, Reno; *franziska.sandmeier@csupueblo.edu*

Persistence of Respiratory Disease in Tortoise Populations: Subclinical Disease, Transmission, and a Possible Dilution-Effect

We re-analyzed data from a transmission experiment, conducted on 277 Mojave desert tortoises (*Gopherus agassizii*) in semi-natural enclosures from 2003-2005. New evidence has emerged that *Mycoplasma agassizii*, a pathogen that causes upper respiratory tract disease (URTD), exists in a subclinical state in many tortoise populations in the Mojave Desert. Tortoises without signs of disease were selected and assigned to three categories: antibody-negative ("negative", but not naïve), antibody-positive ("positive"), and originally "negative", but artificially infected with *M. agassizii* ("infected"). Groups were then paired in enclosures for two years and monitored for signs of disease monthly and antibody levels seasonally. "Negative" groups did not have higher rates of URTD when housed with "positive" or "infected" groups compared to when they were housed with other "negative" groups. However, exposure to recently seroconverting animals or animals with nasal exudate, did lead to greater instances of URTD. Therefore, both the persistence of subclinical disease and transmission from animals with active nasal discharge appear to be important in the maintenance of disease in tortoise populations. "Infected" groups paired with a "negative" group had lower rates of disease than those paired with "positive" group. This would be the first observation of a dilution effect in tortoise populations with URTD. Finally, we found no evidence of immunological memory in tortoises, nor any evidence that antibodies are protective against *M. agassizii*.

P3.146 SANDOVAL, J*; GERSON, A/R; MCCUE, M/D; St. Mary's Univ, Univ Mass Amherst; *mmccue1@stmarytx.edu*

Dehydration causes increased reliance on protein oxidation in mice: a test of the protein-for-water hypothesis in a mammal

During fasting, animals rely on a mixture of fats, carbohydrates, and proteins that are derived solely from endogenous sources. It has long been held that endogenous proteins are spared from catabolism until the final stages of prolonged fasting, and contribute a significant proportion of energy once the other metabolic fuels have been depleted. However, evidence is mounting that protein is catabolized supplemental to fat metabolism under some circumstances. This has been shown in migratory birds that show dramatic reductions in lean mass during flights. One hypothesis to explain this seemingly maladaptive metabolic strategy is that the catabolism and oxidation of protein in situ yields five times more metabolic water than that generated through fat oxidation alone. Here we test the protein-for-water hypothesis in resting mice subjected to water deprivation during fasting while we tracked rates of protein and lipid catabolism using endogenously incorporated ^{13}C-leucine and ^{13}C-palmitic acid. We found no differences in instantaneous leucine oxidation; however, cumulative differences in instantaneous leucine oxidation ultimately resulted in a higher total leucine oxidation after 72h of fasting in water deprived animals. We also found that lipid oxidation was 8% higher in the hydrated mice, but the difference was not significant presumably because of a concomitant reduction in metabolic rates of the water deprived mice. Our results indicate that mammals do increase rates of protein catabolism during dehydration, but to a lesser degree than birds. The ability of mammals to produce highly concentrated urine and their lower inherent rates of protein turnover apparently preclude mammals from taking full advantage of the protein-for-water strategy during fasting under dehydrating conditions.

25.1 SANGER, T*; BRAHMBHATT, P; Loyola University in Chicago; *tsanger@luc.edu*

The Evolutionary and Developmental Bases of Adhesive Toepads in Caribbean Anolis Lizards

Adhesive toepads are considered the key innovation that gave *Anolis* lizards, or anoles, unfettered access to arboreal habitats. Following their origin toepad morphology diversified dramatically among species living in different arboreal habitats. We have investigated the developmental bases for the origin and subsequent diversification of the anole toepad. In *Anolis*, the plantar scales associated with the toepads are the first scales to form on the body, which is a distinct progression of scale development compared to closely related species lacking toepads. Within *Anolis*, the early stages of toepad development are conserved among species. Diversification of toepad morphology appears to occur within the embryo through a common mechanism among all anoles. Using ex ovo culturing techniques with small molecule inhibitors we have also demonstrated that it is possible to developmentally decouple toe scale and toepad development, despite their intimate evolutionary and functional relationships. Our results demonstrate that the the origin and diversification of this key innovation occurred through distinct developmental processes.

P2.196 SANTAGATA, S*; MAHON, AR; HALANYCH, KM; Long Island Univ.-Post, Central Michigan Univ., Auburn Univ.; *scott.santagata@liu.edu*

Marine Ectoproct Communities from the Antarctic Shelf based on Sea Floor Imaging of the Ross and Weddell Seas

Benthic communities of the Antarctic shelf are comprised of a diverse assemblage of species typically dominated by invertebrates, particularly echinoderms, sponges, and ectoprocts. In some zones of the Antarctic shelf ectoproct abundance is significant, creating 'garden-like' habitats that harbor numerous other species. As the combined forces of global warming and ocean acidification threaten these communities, we sought to characterize the ectoproct gardens using direct benthic sampling (Blake Trawls) and two techniques for imaging the sea floor (YoYo camera and OFOS video systems). Blake trawls and YoYo cam transects of the Bellingshausen, Amundsen, and Ross Seas were conducted during a research cruise on the *R/V Nathaniel B. Palmer* in 2013. The OFOS imaging of the seabed in the Weddell Sea was part of the DynAMO project during the PS96 cruise of the *R/V Polarstern* in 2015-16. Species identifications of ectoproct samples were completed using SEM. The areas of ectoproct gardens were measured from the images using the Trainable Weka Segmentation plugin developed for FIJI software. Sites in the Ross Sea contained ectoproct gardens dominated by flustrid species with finely mineralized skeletons, and to a lesser extent by other lepraliomorph and umbonulomorph species having more robust mineralized skeletons. Although ectoproct gardens in Weddell Sea also contained flustrid species, ectoproct species with more heavily mineralized skeletons were more abundant. Combined with species identifications from our fixed samples, the quantification of various morphological grades of ectoprocts was facilitated by the better-resolved images created through the OFOS video system.

119.3 SANTANA, SE*; KALISZEWSKA, ZA; MILLER, LB; RIFFELL, JA; University of Washington; *ssantana@uw.edu*
Bats' response to the plant bouquet: linking bat diet to fruit scent diversity
A fundamental challenge in sensory biology is elucidating the relationship between an organism's sensory adaptations and its ecology. Previous research has demonstrated that frugivorous bats have specialized olfactory systems to locate ripe fruit. However, very few studies have identified the chemicals in the fruit scents that mediate selection of suitable food items, and how these ultimately affect the dietary ecology of bats. The mutualistic relationship between short-tailed fruit bats (*Carollia* spp.) and their primary fruit resource, neotropical pepper plants (*Piper* spp.) are an ideal model system to investigate these questions; they exhibit a gradient of interdependence, and *Carollia* use olfaction to detect *Piper* fruits. We quantified the diet of *Carollia* and the volatile organic compounds (VOCs) that compose the scent of the *Piper* plants they consume in Costa Rica. We further explored if dietary preferences in *Carollia* are associated with differences in VOC types and abundances, or if other factors like plant ecology and density are more important. We found substantial overlap in the chemical composition of fruit scents across *Piper* species that are consumed by *Carollia*, but those that dominate each of their diets are characterized by distinct chemical profiles with a high abundance of a few sesquiterpene hydrocarbons. These results sharply contrast with previous findings in other frugivorous bat lineages that specialize on *Ficus*, and may partially explain differences in the diet and olfactory genomes among independent origins of frugivory in bats.

P3.128 SANTANA RODRIGUEZ, KJ*; GASKIN, AF; COLLIN, R; University of Puerto Rico at Humacao, University of Idaho, Smithsonian Tropical Research Institute; *kelvin.santana@upr.edu*
Factors Influencing Settlement Patterns on the Barnacle Chthamalus panamensis
The gregarious settlement of dominant intertidal organisms, such as barnacles, is essential for recruitment and it's a critical determinant in the structure of the adult population. However, the recruitment density of larvae is largely dependent on physical and temporal factors, which interact dynamically in the intertidal. The barnacle, *Chthamalus panamensis*, found on the Pacific coast of Panamá is a dominant organism that has a higher settlement during neap tides than spring tides. In this study, diel cycles, substrate composition, and other physical parameters (temperature, wind direction, wind speed, and tide amplitude) were studied during the summer 2016 to understand the settlement behaviour of this species, particularly during the quarter moons. Settlement of *C. panamensis*, was higher during diurnal than nocturnal neap tides, which correlated with the warmer temperatures that occur during the day. We expected that bigger tidal amplitude and stronger inshore winds would enhance settlement rate, since this would provide transport and onshore delivery of more planktonic larvae. However, wind speed and wind direction had no significant effect on settlement, while lower tidal amplitude positively correlated with higher settlement rates. As for substrate composition, color was not a strong driving factor for substrate selection since there was no significant difference in settlement rates between the different colored plates. For substrate texture however, settlement was higher on plates with more abrasive sandpaper-like texture that had a more even microstructure. This study provides a better understanding on the settlement patterns of *C. panamensis* and the insight that is gained when considering the interactions among temporal, physical and hydrodynamic conditions that exhibit the intertidal ecosystem.

30.6 SANTINI, F; Associazione Italiana per Studio Biodiversita'; *francesco.santini@alumni.utoronto.ca*
Another look at the evolution of fishes on coral reefs
Coral reefs occupy less than 2% of the oceans, yet are estimated to harbor up to ~ 40% of the extant diversity of marine teleost fishes. Large scale teleost phylogenies have shown that non-reef fish lineages have invaded reef habitats multiple times (probably over 70 times). The vast majority of the reef fish diversity, however, belongs to relatively few groups, prompting the question of what biological traits limit the ability of most clades to take advantage of their new habitats. Furthermore, while earlier studies had found support for the hypothesis that reefs may promote higher rates of lineage or trait diversification in groups such as pufferishes and allies and wrasses, more recent analyses have failed to recover similar patterns in other clades (e.g., jacks, pompanos and allies). In this talk I will present results of comparative macroevolutionary analyses performed using new time-calibrated phylogenies for a number of currently understudied reef-associated fish groups, including snappers (Lutjanidae), breams, porgies and emperors (Sparoidea), morays, snake- and conger eels (Anguilliformes), rabbitfishes (Siganidae), and jacks (Carangoidei). All of these phylogenies have a much denser species sampling than the currently published trees, and use the rich fossil record available for most of these groups. The results show that the relationships between reefs and teleost fishes is very complex, with some traits making some groups much more likely than others to successfully diversify on reefs after invasions.

P3.48 SANTINI, F*; OLIVIER, D; FREDERICH, B; Associazione Italiana per Studio Biodiversita', Université de Liège, Liège; *francesco.santini@alumni.utoronto.ca*
Durophagy influences macroevolutionary patterns in porgies, seabreams and allies (Sparoidea, Percomorpha)
Sparoid fishes form a group of ~ 255 species currently classified in three families (Lethrinidae, Nemipteridae and Sparidae). This group of coastal, demersal fishes shows a remarkable diversity in terms of morphology (body size and shape) and ecology (diet and habitat association). Indeed, various lineages dominate fish communities in temperate soft bottom or rocky reef habitats, while others are major components of tropical coral reef ecosystems. In order to investigate the macroevolutionary pattern of this clade we generated the largest molecular phylogeny for this group, covering ~70% of the extant species diversity and time-calibrated this with seven sparoid fossils. We assembled a dataset of ~ 2300 images from the ichthyological collections of 14 major natural history museums and explored the morphospace of their overall body shape using geometric morphometric methods. We also collected data on body size and species richness from published taxonomic literature and used these data to perform phylogenetic comparative analyses on rates of lineage and phenotype evolution. Our analyses show that the major sparoid lineages all originated during the Late Cretaceous, predating the KPg extinction event. Major bursts of diversification then occurred during the Middle to Late Eocene, as well as during the Miocene, coinciding with dramatic reorganization of coastal benthic communities. We show that durophagy had an important role in driving sparoid evolutionary history. Stochastic mapping strongly suggests that ancestral sparoids were durophagous, while comparison of various models of trait evolution (Brownian motion and Ornstein-Uhlenbeck) shows that durophagy influenced both body size and shape diversification.

73.4 SARGENT, J. C.*; CAMPBELL, J. B.; HARRISON, J. F.; Arizona State University; *james.sargent@asu.edu*

Age-Related Decline of Anoxia Tolerance in Adult Drosophila melanogaster

Cell death occurring from anoxia is considered to be the major pathology for many human diseases such as heart attack and stroke. Though much is known about the cause of anoxia in such conditions, we still have a poor understanding of the mechanisms causing cell death and the genetic and physiological processes responsible for variation in survival of anoxia. *Drosophila melanogaster* are particularly interesting models for studying responses to anoxia as they can survive many hours of anoxia and most of their metabolic pathways are similar to those of humans. Based on studies with humans, we hypothesized that younger adults would have a higher anoxia tolerance than older adults. We exposed adult *Drosophila*, ages 1, 3, 5, 7, 9, and 12 days old, to six hours of anoxia. Survival was assessed 24 hours post-treatment and declined with age in a linear fashion for females and in a more exponential fashion for males. Seventy nine percent of adults one day past eclosion survived six hours of anoxia; while only 10% of twelve-day-old adults survived. Additionally, we measured ATP in 1 and 12 day old *Drosophila* in different durations of anoxia. In anoxia, ATP levels declined rapidly (< 30 min) to near-zero levels in both 1 and 12 day old adults; thus the better anoxia-tolerance of young adults is not due to a better capacity to keep ATP elevated. This age-related decline in anoxia tolerance may be due to loss of capacities to prevent or repair anoxia-related damage. Overall, these data show that patterns of gender- and age-associated variation in tolerance to anoxia are similar in *Drosophila* and mammals, suggesting that *Drosophila* may be underutilized models for studies of the genetic and biochemical mechanisms of pathology of stroke and heart disease. This research was partially supported by NSF IOS 1256745.

93.7 SASSON, D/A*; JAQUEZ, A/A; RYAN, J/F; University of Florida, Lewis & Clark College; *dsasson@ufl.edu*

To Self or Not to Self: Reproductive Strategies of the Ctenophore, Mnemiopsis leidyi

The ability of simultaneous hermaphrodites to self-fertilize (selfing) can be advantageous as it can ensure reproductive success even when partners are rare. However, self-fertilization can lead to inbreeding depression due to low genetic variability, which reduces offspring fitness. Ctenophores (comb jellies) are a group of gelatinous marine predators that are almost entirely simultaneous hermaphrodites capable of selfing. In the ctenophore *Mnemiopsis leidyi*, selfing results in low offspring development and viability. Thus, there may be strong selective pressures to promote out-crossing and reduce selfing. In this study, we examine whether *M. leidyi* can avoid selfing using two potential mechanisms that promote out-crossing: sperm storage and egg trading. Conspecific sperm storage would allow *M. leidyi* to produce out-crossed offspring even when reproductively isolated. We sequenced the offspring of a single isolated individual and found genetic diversity consistent with more than one parent. To test this further, we isolated and spawned individuals for seven consecutive days and conducted paternity analyses on the resultant offspring. This design allowed us to test the ability and duration of sperm storage as well as the frequency of sperm storage within the population. Egg trading occurs when paired simultaneous hermaphrodites reciprocally alternate between shedding eggs and sperm. To test for this behavior, we placed paired *M. leidyi* on opposite sides of a porously divided tank. We found that the number of eggs spawned was highly skewed towards one member of each pair, suggesting that *M. leidyi* alter their reproductive output when spawning in close proximity to another individual. Taken together, these results provide insights into *M. leidyi* reproductive behavior, which is essential to understanding their ecology.

P3.45 SASSON, D/A*; RYAN, J/F; University of Florida; *dsasson@ufl.edu*

The Earliest Animals Did it Alone: Reconstructing the Ancestral Reproductive State of Metazoa

The majority of modern day animal species have separate sexes (gonochorism). However, the ancestral sexual condition (gonochorism or hermaphroditism) is unresolved. Controversies surrounding the relationships of the five major animal lineages (i.e., Bilateria, Cnidaria, Ctenophora, Placozoa, and Porifera) complicate this question. In this study, we reconstruct ancestral sexual conditions of key animal nodes using multiple starting topologies and multiple approaches. We find that the last common ancestor of all animals was most likely a simultaneous hermaphrodite regardless of whether the starting topology has ctenophores or sponges as the sister group to the rest of animals. Furthermore, we find it highly probable that last common ancestor of Cnidaria and Bilateria was gonochoristic. This work establishes the sexual condition of key nodes in animal history and therefore establishes the timing of events that led to major transitions. These data will provide the groundwork necessary for understanding the mechanisms surrounding these transitions, which undoubtedly contributed to some of the most impressive and elaborate morphological traits in the animal kingdom.

81.5 SATTERLIE, RA; University of North Carolina Wilmington; *satterlier@uncw.edu*

Serotonergic Innervation of Wing and Tail Muscle by a Single Neuronal Cluster

The PD-SW cluster of serotonergic neurons of the pteropod mollusc Clione limacina have been shown to innervate the slow-twitch musculature of the wings, and to increase the electrical activity and contractility of those muscle cells. Each pedal ganglion has a cluster of PD-SW cells, however two of the cells do not send axons through the wing nerve to innervate the wing muscle. These two neurons, which have distinct background synaptic activity relative to the other cluster cells, send axons to the tail to innervate the tail musculature. When animals accelerate from slow to fast swimming, inputs to the PD-SW cluster increase firing activity of the neurons, including those that innervate the tail. This supports behavioral observations that increased tension in tail musculature is associated with the acceleratory changes seen in the wing during the change from slow to fast swimming.

36.8 SAVAGE, A.E.*; MULDER, K.P.; TORRES, T.; WELLS, S.; University of Central Florida, Center for Conservation Genomics, Smithsonian Institution, Phoenix Zoo; *anna.savage@ucf.edu*

Lost But Not Forgotten: Class II MHC Genotypes Predict Overwinter Survival Despite Depauperate MHC Diversity in a Threatened Frog

The amphibian disease chytridiomycosis, caused by the fungus *Batrachochytrium dendrobatidis* (Bd), has contributed to the decline of the Federally threatened Chiricahua leopard frog (*Lithobates chiricahuensis*). We characterized immunogenetic variability in L. chiricahuensis by sequencing an expressed Major Histocompatibility Complex (MHC) class II gene across 16 natural populations in Arizona, USA, as well as from 250 individuals that were reared in captivity. We recovered a total of five class II MHC alleles, compared to 83 alleles previously characterized in 11 natural populations of the Arizona congener *L. yavapaiensis*, demonstrating reduced MHC diversity in *L. chiricahuensis*. One allele was fixed in four populations, higher MHC diversity was found at higher latitudes, and none of the *L. chiricahuensis* alleles were closely related to *L. yavapaiensis* allele Q, which is significantly associated with resistance to chytridiomycosis. Twelve *L. chiricahuensis* populations were Bd positive, and Bd prevalence was significantly lower among individuals with homozygous compared to heterozygous MHC genotypes. Three class II alleles were recovered from captive reared individuals, which were released to natural populations for recapture surveys to assess MHC-based survival over winter when chytridiomycosis outbreaks are most severe. All recaptures were of the same MHC genotype, indicating that immunogenetics are important for survival under natural conditions. We conclude that the limited MHC variation in *L. chiricahuensis* is nonetheless important for driving survival in the face of Bd, and may reflect selective sweeps that have removed susceptibility alleles from populations.

94.4 SAXENA, N; NATESAN, D; SANE, SP*; National Centre for Biological Sciences, INDIA; *sane@ncbs.res.in*

How flies determine the location of an odor source

Insects routinely forage in complex sensory environments. Typically the search for a food or pheromone source begins with a whiff of odor, which triggers a flight response. Insects then track turbulent plumes of odor until they approach the vicinity of the odor source. However, pinpointing the precise location of the odor source requires the use of both visual and olfactory modalities. We have investigated the basic rules of this process in the fruit fly, *Drosophila melanogaster* specifically asking how these flies are able to determine the precise location of an odor source amidst a visually cluttered environment. Our experiments show that the decision of flies to land on a putative odor source is biased by the presence of other visual objects in its vicinity. Flies are more likely to land on visually distinct objects that are close to the odor source, if they are of a higher visual contrast. There are significant quantifiable alterations in their search trajectories based on the presence or absence of one or more visually-distinct objects in the vicinity of the odor source. Our experiments also indicate the possibility of olfactory "working memory" that enables them to continue their search even when the olfactory feedback is reduced or absent. Together, these results allow us to gain insight into some basic rules that the flies may use to determine where the source of odor is located.

18.5 SCHACHAT, S.R.; Stanford University & Smithsonian Institution; *schachatsr@si.edu*

Unexpected Morphology and Unprecedented Polymorphism: Does Agathiphaga Clarify or Confuse Relationships at the Base of the Moth Tree of Life?

The order Lepidoptera (moths and butterflies) is the second-most speciose order of animals, and in recent years, tremendous progress has been made in resolving the relationships within and between superfamilies in this order. However, relationships among the most early-diverging families of moths remain unclear; molecular phylogenies are plagued by low support values, and homologies between key morphological characters such as wing veins are still not understood. Moths have an infamously depauperate fossil record, complicating matters further. In 2015, a 3-branched Subcostal vein was predicted to be the primitive character state for all moths; at the time, only 1- and 2-branched Subcostal veins were known from described moths, extant and extinct. A 3-branched Subcostal vein was subsequently found in the genus *Agathiphaga*, confirming the previous prediction and suggesting that this genus may be the most early-diverging lineage of extant moths. The wing veins of *Agathiphaga* show unprecedented polymorphism within a single population: the 3-branched Sc vein is present only in some specimens, and variation also exists in the number of Medial and Cubitus veins. This finding raises questions regarding not only early divergences in the moth tree of life, but also regarding the utility of commonly-used skeletal characters in reconstructing primitive body plans and phylogeny, and the use of extant taxa to reconstruct ancestral states for lineages with depauperate fossil records.

P3.262 SCHACHNER, ER*; SEDLMAYR, JC; SCHOTT, R; LYSON, TR; LAMBERTZ, M; Louisiana State University Health Sciences Center, Wildlife Rehabilitation Center of Minnesota, Denver Museum of Nature and Science, Rheinische Friedrich-Wilhelms-Universität Bonn; *eschachner@gmail.com*

Pulmonary anatomy and aplasia in the common snapping turtle (Chelydra serpentina): perspectives on the evolution of the cryptodiran lung

The lungs of non-avian reptiles have increasingly been of interest to biologists due to their morphological and functional diversity, and more recently, the discovery of unidirectional airflow patterns in the lungs of crocodilians and lizards. Advancements in imaging technology and three-dimensional (3D) visualization software permits the creation of *in situ* digital models of the soft tissues and negative spaces (e.g., the bronchial tree), thus facilitating a better understanding of form and function relationships. Five specimens of *Chelydra serpentina* were utilized for this study: four were examined postmortem, and three were imaged via CT and microCT. The live *C. serpentina* with pulmonary aplasia was imaged for purposes unrelated to this study. The normal bronchial tree of *C. serpentina* demonstrates a narrow primary bronchus that balloons out caudally into an abdominal saccular region. Multiple secondary branches arise laterally and medially in a sequential arrangement from constricted ostia, and dilate towards their distal ends. The pathological *C. serpentina* possesses additional secondary branches, and a more elaborate network of small secondary and tertiary branches. Additionally, the respiratory parenchyma is more homogenous throughout the lung. The aplastic individual also demonstrates some skeletal anomalies, including vertebral scoliosis and convex doming of the ribs. The specific pathology of this *C. serpentina* has the potential to shed light on both the evolution shell shape in aquatic turtles, as well as the evolution of pulmonary structure and lung loss in Testudines and other sauropsids.

P2.261 SCHEFFLER, OR*; AHEARN, G; University of North Florida; *oscheffl@gmail.com*

Disaccharide transport by lobster hepatopancreas

Disaccharide transport across plant membranes has been well-characterized, but only monosaccharides are generally believed to be transported across animal membranes. The present study functionally identified and characterized a disaccharide transporter in lobster (*Homarus americanus*) digestive tract using purified hepatopancreatic brush border membrane vesicles (BBMV), ^{14}C-radiolabelled sucrose, and a Millipore filtration technique. In the absence of sodium, an acidic pH (e.g. pH 4.0) stimulated sucrose uptake by BBMV significantly ($p < 0.05$) greater than occurred at pH 5.0, 6.0, or 7.0. At pH 7.0 inside and outside vesicles, a transmembrane Na^+ gradient resulted in a ^{14}C-sucrose uptake overshoot at 1 min that was significantly greater than vesicle concentration at equilibrium or in the presence of an inwardly-directed K^+ gradient. Experiments using a variety of monosaccharides, disaccharides and trisaccharides, as potential inhibitors of ^{14}C-sucrose uptake, indicated that only maltose and trehalose significantly (one-way ANOVA; $p < 0.05$) inhibited sucrose transport, suggesting a high degree of transport specificity. Detailed carrier-mediated kinetic analysis of the effects of maltose on ^{14}C-sucrose uptake by BBMV showed that maltose significantly increased sucrose transport K_m (control = 0.20 ± 0.06; + maltose = 0.59 ± 0.17 mM) ($p < 0.03$), without affecting its J_{max} (control = 0.58 ± 0.08; + maltose = 0.65 ± 0.13 nmol/mg protein x min) ($p > 0.05$), suggesting that sucrose and maltose were competitive inhibitors and shared a common transport process. Results suggest that lobster hepatopancreatic BBMV possess an SCRT that is proton, or sodium-dependent, carrier-mediated, and shared by sucrose, maltose, and trehalose, and may function to absorb disaccharides that result from digestion of dietary glycogen and chitin.

90.2 SCHERER, AE*; BIRD, CE; HU, X; MCCUTCHEON, M; SMEE, DL; Texas A&M University-Corpus Christi; *avery.scherer@tamucc.edu*

The cost and mechanism of an induced morphological defense in the eastern oyster Crassostrea virginica

Predators can exert strong influence on prey species and entire ecosystems via induced changes in prey characteristics. According to theory, the plastic nature of these prey defenses should indicate a cost, in terms of reduced energy acquisition or altered energy allocation, to the defending prey. However, these defenses are extremely varied and, in many cases, we are uncertain how, or if, these costs manifest. Further, these costs are difficult to predict as we often have a limited or theoretical understanding of the mechanism by which defense induction is achieved. We investigated the mechanism and reproductive costs of a morphological defense in the ecologically and economically important eastern oyster *Crassostrea virginica* in response to crab predators. This predator-prey interaction is more complicated than was previously appreciated, as results suggest oysters shift from a mechanism prioritizing predator escape to one prioritizing predator deterrence as predation risk increases. The more energy-expensive mechanism for deterrence means this defense strategy is associated with proportionally higher reproductive costs at higher levels of predation risk. Additionally, this more elaborate mechanism helps explain the results of several other studies which seemed contradictory or difficult to explain under the assumption of a more simplistic strategy. Our results demonstrate the significance of nonconsumptive predator effects for this foundational prey species which supports a unique marine habitat. Further, they demonstrate the importance of complete defense characterization in the study of phenotypic plasticity.

7.6 SCHILDER, RJ*; HORNETT, EA; MARDEN, JH; Penn State University; *rjs360@psu.edu*

Ecophysiology of infection-associated metabolic disease in a dragonfly

Metabolic disease is not unique to vertebrates but occurs in natural populations of *Libellula pulchella* dragonflies and is caused by midgut-dwelling parasitic protozoan infections. This infection additionally causes impaired flight performance and energetics (and therefore reduced fitness) in male *L. pulchella* dragonflies, but little is known about the proximate mechanisms leading to these impairments, or what determines susceptibility to infection. Causative roles of infection in the development of metabolic disease are poorly understood in any animal system, nor have they often been explored within natural, ecological contexts. Here we present data that start addressing these issues in the *L. pulchella* system and that indicate that variation in soil type and surface water pH at different dragonfly collection sites strongly correlate with observed infection rates at these sites. In addition, we will present preliminary microbiome sequencing data analyses that suggest that microbial composition of the midgut of healthy male dragonflies varies by collection site. Moreover, midgut microbial community composition of infected male dragonflies appears to shifts towards a phenotype that resembles that observed in mammals suffering from metabolic disease. We hypothesize that susceptibility to infection is driven by environmental pH effects on the host midgut microbiome community, and will discuss our ongoing work addressing this hypothesis.

P1.73 SCHMIDT, EC*; SCHAFER, TB; OSBORNE, TZ; Knox College, University of Florida, Whitney Lab for Marine Bioscience; *ecschmidt@knox.edu*

Evaluation of Spatially Clustered Marsh Ponds in a Northern Florida Salt Marsh

Patterned landscapes are naturally occurring phenomena that can reveal major geological or ecological processes taking place in a variety of ecosystems. In a northern Florida salt marsh, there is an abundance of marsh ponds: vegetation-free, almost perfectly circular ponds that have previously not been studied. To begin to understand the origin and role of marsh ponds within salt marshes we evaluated the spatial organization, biogeochemistry, and ecology of the marsh ponds. Using ArcMap we found that marsh ponds were indeed spatially clustered (Average Nearest Neighbor: $p<0.005$; Global Moran's I: $p<0.005$). We then took soil cores from a pond and a marsh site using a 1m long push core. We found that marsh ponds had higher ranges of organic matter deeper in sediment profiles (17.6% - 25.4%) compared to the neighboring marsh (3.9% - 8.7%). Additionally, marsh ponds had relatively high iron levels (1,410 mg/kg) deeper in the profile (62-64 cm depth) compared to the neighboring marsh (381 mg/kg). Our results suggest groundwater influence, which is a major feature of karst landscapes. We hypothesize that marsh ponds formed through karst dissolution. However, pore water samples measuring salinity, pH, and sulfide levels from varying depths found no evidence to suggest groundwater influence but these erratic measurements could be explained by a drought at the time of collection. Finally, we monitored the abundance of organisms in the ponds using crab and minnow traps. We found that blue crabs were more abundant in ponds than in nearby streams suggesting that marsh ponds act as refugia for small organisms. Overall, our work lays the groundwork for future studies examining the geologic processes underlying marsh pond formation as well as their ecological role in salt marshes.

P2.88 SCHNEIDER, KA*; SHEWADE, LH; BUCHHOLZ, DR; SCHNEIDER, Kateli; University of Cincinnati; *schneik9@mail.uc.edu*

Characterization of a Corticosterone Response Gene in Xenopus Tropicalis

Mechanisms underlying the developmental origins of chronic adult diseases have yet to be determined. An important finding is that stress experienced during early life causes higher basal stress hormone levels, leading to later life behavioral, neural, and metabolic changes. To elucidate how stress hormones impart the lasting effects of stress, we use frog metamorphosis as a model. Amphibian metamorphosis is mediated by thyroid hormone (TH), and stress hormone Corticosterone (CORT) synergizes with TH to accelerate metamorphosis. The effects of CORT on development and subsequent altered stress hormone levels are conserved in tadpoles and humans. Towards the overall goal of understanding the mechanisms of permanent effects of stress on development, I am characterizing Str. 34945, the only known CORT-response element not also regulated by TH. The Str. 34945 sequence maps onto the Xenopus tropicalis genome in between the genes *ush1g* (Usher syndrome 1G) and fads6 (fatty acid desaturase 6), but it is unclear if it is part of one of these genes or if it is a noncoding RNA sequence. Based on our data, this gene is *ush1g*. In an effort to determine how and where Str. 34945 is expressed in the tadpole, we treated the animals with CORT and measured Str. 34945 expression via qPCR. When tadpoles were treated with CORT for 24 hours we found Str. 34945 is upregulated in the whole tail, tail muscle, lungs, liver, and heart; it is not expressed in the brain or kidney. Furthermore, we show Str. 34945 is consistent with the only other known CORT response gene and shows the expected expression profile based on normal CORT changes through metamorphosis. Our results demonstrate that Str. 34945 can be a unique tool to specifically detect the presence of CORT.

S3.9 SCHNEIDER, Jill E.*; BENTON, Noah; RUSSO, Kim; BROZEK, Jeremy; KRIEGSFELD, Lance; Lehigh University, University of California, Berkeley; *audryfarber@gmail.com*

The Role of GnIH in the Tradeoff Between Reproductive and Ingestive Behavior

Adaptation requires successful reproduction, but reproductive processes are energetically expensive and can compromise the chances of survival during energetic challenges. Previous work examined the inhibition of the hypothalamic-pituitary-gonadal system and stimulation of food intake during severe energetic challenges by chemical messengers, including the RFamide-related peptide, gonadotropin-inhibiting hormone (GnIH). Recently, we examined the role of GnIH in female Syrian hamsters under mild energetic challenges with particular attention to appetitive behaviors, such as food hoarding and the preference for spending time with male conspecifics. We found a strong link between brain GnIH cell activation and food restriction-induced changes in appetitive, but not consummatory behaviors. Food restriction-induced increases in GnIH cell activation and food hoarding and decreases in sexual motivation were apparent on all days of the estrous cycle except the day of proestrous and in ovariectomized (OVX) females, but not in OVX females treated with progesterone alone or estradiol plus progesterone. Central treatment with GnIH in *ad libitum*-fed females was sufficient to significantly decrease preference for males and produce transient increases in food hoarding, but substantial knock down of GnIH gene transcription by RNA interference had no effect on food restriction-induced changes in appetitive behaviors. Thus, in environments where energy availability fluctuates, reproductive success may be optimized by the interactive effects of GnIH (and possibly other peptides) with progesterone on appetitive but not consummatory behavior. Funded by NSF grants IOS-1257638 and IOS-1257876.

58.1 SCHNITZLER, CE*; NGUYEN, AD; KOREN, S; GORNIK, SG; PLICKERT, G; BUSS, L; PHILLIPPY, A; MULLIKIN, JC; CARTWRIGHT, P; NICOTRA, ML; FRANK, U; BAXEVANIS, AD; U. Florida, NHGRI, NIH, NUI-Galway, U. Cologne, Yale U., NISC, NHGRI, NIH, U. Kansas, U. Pittsburgh; *christine.schnitzler@whitney.ufl.edu*

Comparative genomics of Hydractinia and Hydra

Comparative genomic approaches applied to cnidarian genomes can provide a powerful framework for exploring fundamental questions about the evolution of complex biological processes such as embryonic development, regeneration, self-recognition, and aging. We have chosen to focus on the colonial cnidarian *Hydractinia*, a hydrozoan representative that has lost the medusa stage and produces gametes directly from sexual polyps known as gonozooids. *Hydractinia* forms colonies of clonal polyps interconnected through a stolonal network and, in nature, colonies are typically found on shells inhabited by hermit crabs. We formed an international consortium and generated high-quality, high-coverage genome assemblies for *H. echinata* and its sister species, *H. symbiolongicarpus*, using PacBio, Illumina, and Dovetail sequence data. The estimated genome size is 774 Mb for *H. echinata* and 514 Mb for *H. symbiolongicarpus*. Similar to *Hydra*, both genomes are AT-rich (65%) and highly repetitive (at least 47%). We are using a comparative genomics approach where we (1) assess differences in gene content when compared to a recently updated high-quality *Hydra* Dovetail genome assembly; (2) explore regions of possible synteny among the genomes; and (3) compare non-coding RNAs, classes of repetitive elements, and conserved gene families. Interesting themes have begun to emerge in each of these areas that will ultimately reveal both the conserved features and extensive evolutionary novelties contained within these model hydrozoan genomes.

P1.141 SCHOENEMANN, KL*; MONTREUIL-SPENCER, C; BONIER, F; Queen's University; *k.schoenemann@queensu.ca*

A Picture Worth 1000 Words: What Does a Snapshot of a Physiological Trait Tell Us About Individual Variation?

Many physiological traits are plastic: to maintain allostasis, an organism alters its central nervous, immune, and endocrine systems to respond to changing environments and energetic demands. However, organisms can also exhibit consistent individual differences relative to other individuals. This contrast between individual plasticity and consistency raises the question: to what extent does a single measurement of these labile traits represent individual differences? To address this question, we measured three physiological traits in 56 free-ranging black-capped chickadees (*Poecile atricapillus*) at two time points during the non-breeding season. Specifically, we measured the stress hormone corticosterone, which is important in regulating behavioral and physiological responses to challenges; total antioxidant capacity and reactive oxygen metabolites, which provide a measure of oxidative stress; and the hemolytic activity of plasma, which provides an index of immune function. We present the repeatability of these three metrics and their interrelationships. Many field biologists seek to characterize study subjects in terms of parameters of condition, fitness, or quality using a single measurement of a physiological trait. Our findings will help inform interpretations of such point measures of physiological traits.

142.6 SCHOENLE, LA*; KERNBACH, ME; MOORE, IT; BONIER, F; Virginia Tech, Virginia Tech, University of South Florida, Virginia Tech, Queen's University; *schoenle@vt.edu*

Why Does Malaria Infection Reduce Fitness in Wild Birds?: A Test of Physiological Mechanisms

Haemosporidian parasites, including those responsible for avian malaria, can have substantial negative fitness consequences for their avian hosts. In areas where the parasites have been recently introduced, acute infection can result in rapid mortality. Where the parasites are endemic, infection does not have similar effects, but chronic infection can reduce both annual survival and reproductive success in some bird species. As a result of the parasites' global distribution and the sublethal effects of chronic infection, malaria-causing parasites are frequently used as a model to test the role of parasites in shaping life history evolution. However, the mechanisms underlying the relationship between chronic malaria infection and fitness are not well understood. We investigated some physiological consequences of low intensity, chronic infection in adult male red-winged blackbirds (*Agelaius phoeniceus*) from a population where approximately 95% of individuals are infected. We used a medication experiment with birds held in outdoor aviaries to examine the effects of infection on 1) cellular damage, 2) tissue repair, and 3) immune activation. Higher parasite burdens were correlated with lower hematocrit and an increase in red blood cell production. Birds that received antimalarial medication had higher hematocrit and hemoglobin, reduced rates of red blood cell production, and increased body mass relative to controls. We detected no effect of infection on oxidative damage, two metrics of the immune response, or circulating glucocorticoid concentrations. Our results suggest the physiological costs of malaria infection can be substantial and could relate to the cost of replacing red blood cells damaged during infection.

P3.28.5 SCHOEPF, I.*; SCHOENLE, L.; MOORE, I. T.; BONIER, F.; Virginia Tech, Blacksburg, VA, USA, Queen's University, Kingston, On, Canada; *i.schoepf@vt.edu*

Pain and gain: does increased tolerance to a parasitic infection implicate other health parameters and carry energetic costs in a migratory passerine?

Energy is limited and must be allocated among competing functions. Allocation of energy to one function can carry fitness costs through reduced energy availability to other functions. For example, individuals facing a health challenge, such as a parasite infection, might respond by shifting resources previously allocated to other life-history functions in favor of fighting said infection. Trade-offs might also exist within the same function. For instance, investing in one health parameter may implicate another. In a previous study, we found that adult male red-winged blackbirds (*Agelaius phoeniceus*) with higher corticosterone have greater tolerance to the Haemosporidian parasites that cause malaria. However, we do not know whether individuals with higher malarial tolerance (measured as reduced loss in hematocrits and hemoglobin) implicates health in other ways or is linked to increased costs in terms of energy expenditure, and thus if there is a trade-off between corticosterone and any of these functions. Here, we present the result of a study aimed at testing whether higher corticosterone and tolerance to malaria is associated with: 1) higher energy and metabolic expenditure, 2) higher oxidative stress, and/or 3) overall health. We test these predictions using measures of corticosterone, hematocrits, hemoglobin, glucose, oxidative stress, and intensity of malarial infection in wild red-winged blackbirds. The results of this study are part of broader research looking at the coping mechanisms employed by individuals to respond to infections.

P1.191 SCHOOLMAN, PT*; STAAB, KL; McDaniel College; *pts005@mcdaniel.edu*

Cranial morphology of the pearly lanternfish, Myctophum nitidulum

Myctophids, commonly referred to as lanternfishes, constitute the majority of all deep-sea biomass and are known for their ecological importance in the oceanic food web and as a major component in global oceanic carbon distribution. Recent molecular phylogenies suggest that myctophids are sister to acanthomorphs, a species-rich clade that has evolved the ability to protrude the upper jaw during feeding. Despite the documented significance and importance of myctophids, their cranial morphology is vastly understudied and little is known about how these fish feed. Because myctophids are considered to be the outgroup to Acanthomorpha, studying the cranial morphological characters may provide clues on the evolution of the premaxillary protrusion feeding mechanism in acanthomorphs. Here we document the cranial anatomy of *Myctophum nitidulum*, with a focus on the soft tissue linkages within the jaws and between the jaws and the rest of the cranium. *M. nitidulum* has a relatively large gape, averaging 50% of the overall head length. A rostral cartilage is present caudoventral to the ascending processes of the premaxillae, which are relatively small compared to the ascending processes found in acanthmorph species. The rostral cartilage in *M. nitidulum* is similar to the rostral cartilage that is common in acanthomorphs. A band of dense fibrous connective tissue tightly binds the premaxillae to the maxillae and to the rest of the head, which prevents the possibility of upper jaw protrusion. Understanding the various morphological characters of myctophid jaws not only facilitates development of hypotheses on the evolution of premaxillary protrusion in acanthomorphs, but also allows for inferences on the functional aspects of prey capture and processing in a family of fishes that are a vital component in the circumglobal oceanic food web.

P3.28 SCHREIER, KC*; GRINDSTAFF, JL; Oklahoma State University; *kaati.schreier@okstate.edu*

Are Behavioral and Immunological Strategies Against Disease Repeatable in Zebra Finches?

Disease exposure is a universal threat to all organisms, and self-defense can occur in a variety of ways. Individuals can proactively prevent disease through avoidance behaviors. But, if they become infected, individuals can activate the immune response to control the infection. It is hypothesized that a trade-off occurs between avoidance behaviors and immune response activation because of costs associated with each strategy. Individuals may balance behavioral and immunological strategies to provide optimal protection against disease. It is unknown if individuals are consistent in their choice of strategies over time or if they modify their strategies based on situational indicators or life-history stages. With a captive population of zebra finches (*Taeniopygia guttata*), we conducted two-choice behavioral trials to determine how much time a focal bird would associate with a sick or healthy stimulus bird. We then inoculated focal birds with lipopolysaccharide (LPS) and collected blood samples to measure levels of natural antibodies, complement, and acute phase protein. The same subset of individuals was tested three times over a three month time frame to measure repeatability of behavior and immune responses. We predict that an individual's immunological measurements will correspond to their association behavior and that strategy choice will be variable over time. It may be more advantageous for individuals to alter their disease defenses based on environmental contexts and exhibit behavioral plasticity than to have fixed strategies. Determining how the innate immune response can change over an extended period of time may bring new insights into social interactions and the potential spread of wildlife diseases.

P3.233 SCHROEDER, RT*; CROFT, JL; BERTRAM, JEA; Biomedical Engineering, University of Calgary, AB, Canada, Centre of Exercise and Sports Science Research, School of Medical and Health Sciences, Edith Cowan University, Perth, Australia, Cumming School of Medicine, University of Calgary, AB, Canada; *ryan.schroeder@ucalgary.ca*

Exploring the Dying Art of Traditional Load Carrying: Mechanical Properties of Bamboo Farmworker Poles in Vietnam

Many cultures in Southeast Asia craft flexible bamboo poles for carrying heavy loads on their shoulder. Influenced by elastic pole qualities, carriers often entrain their body motions to resonant load oscillations. Previous studies suggest this may reduce peak forces on the shoulder or energetic costs of locomotion. Still, a thorough explanation of these effects remains ambiguous. In order to develop explanatory models, mechanical properties of authentic poles should be characterized. With this in mind, we recently travelled to a rural farm town in north Vietnam where we tested poles in use at a local farm. Authentic poles were purchased and brought back to our lab for further testing of material/structural properties. Resonant frequency and signal damping were characterized for free vibration under various loads. Force-deflection curves were created for loading and unloading. Integration of these curves gave hysteresis, and slope was determined to characterize stiffness. Photogrammetry was also used to develop 3D models of each pole's unique geometry. We found a non-linear resonance consistent with simple beam theory at various loads. Low damping ratios (<0.03) and hysteresis (2-10%) confirmed resilient qualities of the bamboo. Stiffness spanned a range (1.5-3.3kN/m). By cataloguing the mechanical properties described here, we hope to gain insight into this unique tool for load carriage and contribute to the preservation of a remarkable tradition slowly dying out, largely due to increased mechanization on the farm.

142.1 SCHULTZ, EM*; KLASING, KC; HAHN, TP; Kenyon College, Univ. of California, Davis; *schultz1@kenyon.edu*

Modulation of reproductive physiology and cytokine expression by changes in photoperiod and immune challenge in red crossbills

Seasonal variation in environmental conditions such as temperature, food availability, and likelihood of disease influence an organism's investment in costly physiological processes such as immune function and reproduction. Most temperate zone organisms use changes in day-length (photoperiod) as an initial predictive cue to time physiological investments to coincide with optimal environmental conditions such as peak food availability and benign temperatures. Red crossbills *Loxia curvirostra* are temperate zone songbirds that time reproduction to coincide with booms in conifer seeds, their preferred food resource, often in extreme environmental conditions. In this experiment, to determine if changes in photoperiod and/or food availability affected investment in innate immunity, crossbills were exposed to either long day-lengths (LD) or short day-lengths (SD) for six weeks before experiencing a 20% food reduction for a period of 10 days or continuing on an ad-libitum diet. Additionally, the acute phase response was induced by injecting lipopolysaccharide (LPS) both before and after diet change. Liver, spleen, and gonadal tissues were taken from sacrificed birds 22 days post experimental end. At this time, all birds had access to ad-libitum food but remained on the same experimental photoperiod. LDs decreased cytokine interleukin (IL)-10 mRNA expression in the liver and IL-4 and IL-6 expression in the spleen, but increased total testes volume in males. Birds that had been LPS challenged and kept on SDs had lower IL-4 and higher toll-like receptor (TLR)-4 expression in the liver. Effects of treatments on cytokine and reproductive physiology were determined by GLMs and AICc to assess weight and fit of all models.

106.6 SCHULZE, A; Texas A&M University at Galveston; *schulzea@tamug.edu*

Conserved Mechanisms of Oxygen Sensing in the Bearded Fireworm, Hermodice carunculata (Annelida: Amphinomidae)

The bearded fireworm, *Hermodice carunculata* (Annelida: Amphinomidae), is a ubiquitous species throughout the temperate and tropical Atlantic, the Caribbean, Gulf of Mexico and Mediterranean Sea. It is particularly common in disturbed areas where dissolved oxygen (DO) tends to be low. To examine gene expression responses to low DO in this species, RNA-Seq data from individuals collected in the field as well as from controlled laboratory experiments are analyzed. Some of the key players of oxygen sensing which are highly conserved throughout metazoans are Hypoxia Inducible Factor (HIF), HIF Prolyl Hydroxylase (PHD) and Factor Inhibiting HIF (FIH). Hypoxia Inducible Factor is a heterodimeric transcription factor, consisting of an alpha subunit, which is unstable under normoxic conditions due to hydroxylation by PHD and/or FIH, and a stable beta subunit. All of these components have been identified in the *H. carunculata* transcriptome and their conserved domain structure characterized. This study provides the first record of the conserved oxygen sensing cascade in annelids. Future research will elucidate the downstream processes in the hypoxia response.

P3.69 SCHUMANN, W,P*; SWALLOW, J,G; GREENE, M,J; University of Colorado Denver; *william.schumann@ucdenver.edu*

How an individual brain can lead to societal change in pavement ants (Tetramorium caespitum)

Ants have miniaturized brains yet they exhibit surprisingly complex behaviors. In social insect colonies, individuals gather information, integrate it, and compare that information to an inherent set of rules to make behavioral decisions. Many individual decisions can lead to the self-organization of complex behaviors at the level of the colony. However, little is known about the proximate mechanisms behind these collective behaviors. The brain monoamines octopamine, dopamine and serotonin play a significant role in regulating insect behavior. I use pavement ants (*Tetramorium caespitum*) as a model species to understand how brain neurochemistry regulates collective social behavior. Pavement ants engage in conspicuous battles with non-nestmate colonies that are easy to manipulate and observe. My research attempts to determine how serotonin regulates individual decisions which lead to complex, collective behaviors. Standard immunohistochemistry (IHC) was used to map the distribution and activity of serotonin under different behavioral contexts: social isolation, cooperative social behavior (trophollaxis, allogrooming), and antagonistic response to a non-nestmate. IHC stained for serotonin and the neuronal marker for activity, cFos. I will present data that show the distribution of serotoninergic neurons and the active regions in the pavement ant brain during specific behaviors. In this way we can see the mechanisms behind the individual behaviors that can lead to complex, collective behaviors.

79.4 SCHUPPE, ER*; FUXJAGER, MJ; Wake Forest University; *schuer15@wfu.edu*

Longer and Faster drum signals are associated with enhanced competitive ability in territorial woodpeckers

Physically elaborate social signals are believed to evolve because they reflect an individual's quality by showcasing vigor, or an ability to produce energetically demanding behavior. However, many studies fail to uncover a relationship between vigor and individual variation in reproductive success. Here, we use the downy woodpecker to experimentally test an alternative hypothesis, which posits that physical displays evolve in response to sexual selection for motor skills. This species communicates with conspecifics by rapidly and repeatedly striking their bills against resonate surfaces at approximately 15 Hz (strikes/second), and the result is a sonation, called a drum, which is used for territorial signaling. We therefore modulate the acoustic parameters of the drum that represent underlying motor skill. Specially, we generated drums that either included more beats or a shorter duration between two beats to assess how these factors influence territorial behavior of resident birds. Our findings demonstrate that slightly longer and faster drums elicit a more robust aggressive response, suggesting that breeding pairs evaluate aspects of the drum that are reliant on motor skill when deciding how to respond to competitors. Furthermore, using quantitative PCR, we illustrate that at least one physiological adaptation that may enhance motor command, the amount of androgen receptor expressed in a skeletal muscle, is associated with the downy woodpecker's neck musculature. These data collectively suggest that sexual selection for motor skill is associated with the emergence of an elaborate physical display in woodpeckers.

1.5 SCHWAB, J.L.*; COUNTERMAN, B.A.; Mississippi State University; *Jlynschwab@gmail.com*

How to Build a Pink Butterfly: an Investigation of the Developmental and Environmental Influences on Color Plasticity in the Southern Dogface Butterfly

The vast array of natural variation that we see around us has been generated through a combination of genetic and environmental influences. Traits that are environmentally induced within species, but are genetically different between species provide a framework for identifying the developmental pathways that drive the evolutionary process. Butterfly wing patterns provide an amenable evolutionary model to study these genetic and environmental interactions. The Dogface butterfly, *Zerene cesonia*, is a seasonally polyphenetic butterfly that varies in both pigment and structural coloration. The seasonal forms are comprised of an Ultraviolet reflecting yellow Summer morph and an Ultraviolet lacking pink Winter morph. These within-species morph differences are also very similar to color differences between *Z. cesonia* and its sister species the California Dogface, *Zerene eurydice*. Given the segregation of these colors both within and between species, these two colors may be jointly controlled by the same developmental pathways. If these colors are jointly controlled then we expect to see a shared environmental trigger leading to a shared developmental response. To test this we have 1.) Investigated the environmental triggers responsible for both colors, 2.) Quantified UV changes in shape and brightness, and 3.) Identified the developmental causes of pink coloration. Overall this work suggests that there may be a shared environmental and developmental mechanism between a pigment and structural color in the Southern Dogface Butterfly.

124.4 SCHWALBE, MAB*; COUGHLIN, LL; MUKHERJEE, R; TYTELL, ED; Tufts University; *margot.schwalbe@tufts.edu*

Bluegill Sunfish (Lepomis macrochirus) Are Stable to Horizontal Vortices With and Without Their Lateral Line and Visual Systems

Fish swim in complex hydrodynamic environments and probably rely on multiple sensory modalities for stabilizing swimming in unsteady flows. It is unclear how the lateral line system and vision contribute to a fish's ability to compensate for different types of unsteady flows, including horizontal vortices (like those shed by waterfalls in a stream). Here we tested the relative importance of the lateral line system and vision in bluegill sunfish (*Lepomis macrochirus*) swimming in horizontal vortices generated by a custom-made flapper. To examine the importance of vision, swimming behavior was filmed under infrared light, and to examine the importance of the lateral line, fish were treated with cobalt chloride to temporarily deactivate the lateral line system. During each trial, a fish was positioned behind the flapper (frequency = 0.5 Hz) while swimming at 0.28 body lengths/s and recorded with two high-speed cameras to obtain the center of mass velocity, the fish's relative distance and elevation to the flapper, any changes in orientation, and movement of its caudal fins relative to the flapper's movement. Interestingly, few differences from the control were observed when vision, or the lateral line system, or both were disabled. Fish swam closer to the flapper when their lateral line systems were inactivated, but they did not change their velocities, elevation, or orientation towards the flapper. Caudal fin movements also did not change significantly during the different trials. Therefore, passive properties of the fish's body likely played a greater role in maintaining stability while swimming in horizontal vortices than sensory input from the lateral line and visual systems.

128.2 SCHWANER, MJ*; LIN, DC; MCGOWAN, CP; University of Idaho, Moscow, Washington State University, Pullman, University of Idaho, WWAMI Medical Education Program, Moscow; *janneke.schwaner@gmail.com*

Muscle Dynamics During Vertical Jumping by Kangaroo Rats (D. deserti)

Predation is an important factor that shapes prey's fitness. Kangaroo rats (*D. deserti*) are bipedal hoppers that do not only outrun but also ‘out-jump' predators, as they perform vertical jumps to evade their attacker (i.e., snakes and owls). Reported vertical jumps of this animal can reach more than 1 meter, which is over 20 times hip height; however under laboratory conditions, we see maximal jumps of approximately 10 times hip height. The lateral gastrocnemius muscle (LG) is one of the primary muscles involved in plantar flexion, and likely plays a key role in propelling the animal upwards during vertical jumping. In this study we examined the relative mechanical work contribution by the LG muscle to the vertical jumps of kangaroo rats. We hypothesized that the amount of work done by the LG is a fixed percentage of the energy required for a jump. We examined the in vivo performance of the LG muscle during vertical jumping by combining high speed video and ground reaction forces for inverse dynamics, along with sonomicrometry and EMG data. Preliminary data suggest that our hypothesis is supported. There appears to be a linear relationship between actual jump height and work done by the LG muscle. This suggests that the LG muscle is required to perform more work as the height of the jump-task increases. Future research will include a more detailed analysis of joint and muscle dynamics as well as analysis of additional leg muscles.

P3.214 SCHWARTZ, M.K.*; OLBERDING, J.P.; University of South Florida; *mevanskeene@mail.usf.edu*

Tradeoffs in Swimming and Jumping Performance in Aquatic and Arboreal Frogs

Adaptations for one behavior may lead to tradeoffs in performance of other behaviors. For example, the aquatic frog, *Xenopus laevis*, has morphology advantageous for swimming including a mobile ilio-sacral joint, extensively webbed hind feet, and a streamlined body. However, frogs that live in aquatic environments tend to have lower jump performance than more terrestrial species. The arboreal frog, *Osteopilus septentrionalis*, has morphological adaptations including long hind limbs and muscle-tendon units used as elastic-recoil mechanisms that confer high jump performance. We examined swimming and jumping in *Osteopilus* and *Xenopus* to compare performance of these species. We expected to see higher jump performance in *Osteopilus*, but higher swimming performance in *Xenopus*. Jumping and swimming were recorded for both species using high-speed video. The highest values of peak velocity and acceleration of both swimming and jumping for an individual were analyzed. The average peak velocity of jumping for *Osteopilus* (2.5 m/s) was significantly higher than *Xenopus* (1.3 m/s), but there was no significant difference in average peak velocity for swimming between *Osteopilus* (0.94 m/s) and *Xenopus* (0.95 m/s). A similar pattern was seen for average peak acceleration. These results support the tradeoff between swimming and jumping in *Xenopus*, but show no tradeoff for *Osteopilus* in these parameters. The adaptations for high performance jumping seen in *Osteopilus* may not be detrimental to swimming performance. Alternatively, the swimming abilities of *Osteopilus* may be adaptive as these frogs do enter water. Additional analyses may reveal tradeoffs in other measures of performance like efficiency or endurance.

P3.234 SCHWARTZ, NL*; PATEL, BA; GARLAND JR. , T; HORNER, AM; California State University, San Bernardino, University of Southern California, University of California, Riverside; *schwartz.l.nicolas@gmail.com*

The effects of selection and exercise on femur morphology in mice selected for high running

Bone is a dynamic tissue functioning to maintain mineral homeostasis, and provide mechanical support for the body. In the absence of mechanical stimuli (i.e., disuse), net resorption of bone occurs. Uniquely, bone can be influenced by intrinsic (e.g. genetics) as well as extrinsic (e.g. mechanical loading) factors. Bone remodeling requires increased oxygenation and blood flow. Nutrient vessels account for 50-70% of long bone blood supply in amniotes, therefore foramina may serve as good proxies for metabolic intensity. To consider the separate and combined influences of genetics and mechanical loading, we used mice from 4 replicate lines selectively bred for high levels of voluntary wheel running (HR) from generations 11, consisting of males and females, and generation 71, consisting of female mice trained for over 12 consecutive weeks and untrained counterparts. We hypothesized that foramen area would be greater in more metabolically active mice. To evaluate this, femoral foramen area (total), cortical thickness of diaphysis, length, volume, moment of inertia, and polar moment were measured via micro-computed tomography. Expected differences are: sex-specific within generation 11 as females run more than males, selection-specific within generations 11 and 71 as HR have higher voluntary metabolic activity than controls, training-specific within generation 71 as training yields greater endurance capacity and affects bone properties, and long-term selective effects as continued selection for wheel running increases morphological and anatomical differences between selected and control lines.

57.4 SCHWEIKERT, LE*; GRACE, MS; Duke University, Florida Institute of Technology; *lschweikert2011@my.fit.edu*

Visual Anticipation of New Photic Environments by the Developing Retina of the Atlantic Tarpon (Megalops atlanticus)

Fish that undergo ontogenetic migrations between habitats often encounter new light environments that require changes in the spectral sensitivity of the retina. For many fish, sensitivity of the retina changes to match the environmental spectrum, but the timing of retinal change relative to habitat shift remains unknown. Does retinal change in fish occur in anticipation of habitat shift, or is it a response to encountered changes in environmental light? Spectral sensitivity changes were examined over the development of the Atlantic tarpon (*Megalops atlanticus*) retina relative to ontogenetic shifts in habitat light. Spectral sensitivity of the retina was determined by electroretinography and compared to the spectral irradiance of habitats occupied by *M. atlanticus* from juveniles to adults. These data, along with previously known microspectrophotometric measurements of sensitivity in *M. atlanticus*, indicate retinal spectral sensitivity that matches the dominant wavelengths of environmental light for juvenile fish. For sub-adult *M. atlanticus*, however, spectral sensitivity does not match the dominant wavelength of light it occupies, but better matches the dominant wavelengths of light in the habitat of its forthcoming migration. These results indicate that the relationship between environmental light spectrum and spectral sensitivity of the retina changes during *M. atlanticus* development and suggest that such changes may be programmed to support visual anticipation of new photic environments.

6.2 SCIOLI, JA*; FELDER, DL; University of Louisiana, Lafayette; *jas0409@louisiana.edu*

Molecular Phylogeny of the Alpheus "macrocheles" Species Group in the Tropical Western Atlantic Uncovers Undescribed Diversity

The genus *Alpheus* constitutes one of the most speciose genera of decapod crustaceans. A group of species related to *A. macrocheles*, one of seven species groups erected by Kim & Abele (1988), is united by teeth on the margins of the orbital hoods and a twisted, compressed major cheliped. This group presently includes eight species that occur in the western Atlantic. Several previous studies have suggested that one in particular, *Alpheus amblyonyx*, represents a species complex. We present a molecular phylogeny including four members of the "macrocheles" group. We utilized two mitochondrial genes, Cytochrome Oxidase I (COI) and 16S rRNA as well as nuclear marker Histone H3. Our results suggest that material identified to *Alpheus amblyonyx* constitutes two distinct clades, one of which is presently undescribed. The clade representing a likely new species included specimens exclusively from deeper Gulf of Mexico waters (42-246m), whereas *Alpheus amblyonyx* s.s. was collected from shallow water in the Caribbean. This potentially new species has morphological affinity to *A. cedrici* from Ascension Island, *A. macrocheles*, from the eastern Atlantic, and *A. pouang*, from Brazil. Present lack of comparable sequence data for these species for now limits study of their evolutionary relationships with the undescribed Gulf of Mexico clade. Further investigation of genetic relationships between members of the group worldwide is necessary to properly revise taxonomy and systematics of this alpheid complex.

117.3 SCOTT, B*; WILGA, C; BRAINERD, E; Univ. of Rhode Island, Univ. of Alaska, Anchorage, Brown University; *bradley_scott@uri.edu*

Three-Dimensional Motion of the Hyoid Arch of White-Spotted Bamboo Sharks, Chiloscyllium plagiosum, using XROMM

Some elasmobranchs converge with teleost fishes on the use of suction as a feeding strategy, but elasmobranchs use different mechanisms for generating suction. In contrast to teleost fishes, elasmobranchs have decoupled depression of the lower jaw from expansion of the hyoid arch. Also, in teleosts the hyoid apparatus produces both ventral and lateral expansion, whereas in elasmobranchs ventral expansion is coupled with lateral compression. Bamboo sharks are suction specialists with performance that surpasses that of teleost suction specialists, despite having fewer elements in the hyoid arch and with less contribution from the oral jaws. This study reconstructs the three-dimensional kinematics of the hyoid arch in bamboo sharks (n=3 individuals and 4 strikes per individual) during feeding using X-ray Reconstruction of Moving Morphology (XROMM). Points on the distal hyomandibula and proximal ceratohyal of the hyoid arch move ventrally and medially as expected, while the ceratohyal retracts by an impressive 43.4±2.0 degrees relative to the cranium. Substantial long-axis rotation of both elements up to 50 degrees was revealed, a phenomenon that was not visible in feeding structures using conventional methods. During hyoid depression, the dorsal surface of the hyomandibula rotates rostrally while that of the ceratohyal rotates caudally. Depression of the hyoid elements increase with long-axis rotation, while protraction and retraction of the hyoid varies independent of the magnitude of depression. Hyoid motions of the bamboo shark are more complex than previously thought. Long axis rotation coupled with extreme hyoid retraction enables bamboo sharks to generate as much as 100kPa of subambient pressure to suction prey from crevices around coral reefs.

P3.60 SEARS, CR*; STAHL, BA; GROSS, JB; University of Cincinnati; *searscr@mail.uc.edu*

Potential roles for pmela and tyrp1b in pigmentation patterning in the blind Mexican cavefish, Astyanax mexicanus.

Upon colonizing the cave environment, the blind Mexican cavefish, *Astyanax mexicanus*, has evolved a variety of extreme phenotypes that contrast starkly with the extant surface morphotype. Degenerative traits such as a visual system and pigmentation have been extensively documented in this system, based on direct comparisons between derived cave morphologies and the (surrogate) ancestral, surface forms. Little is known, however, of the complex gene network controlling melanophore patterning in this system. In this study, we focused on two genes, *pmela* and *tyrp1b*. These genes are jointly involved in variations of melanosome shape and number, and early melanoblast development in zebrafish. Using analysis of cross-developmental *in-situ* hybridization and gene knockdown by morpholino, we established clearer roles of *pmela* and *tyrp1b* in *Astyanax* pigmentation development. Based on *in-situ* hybridization quantification, we observed the greatest divergence between morphotypes at 21-24 hpf. The total number of *tyrp1b* or *pmela* positive cells was not significantly different between cave and surface fish; however, *tyrp1b* was expressed in a significantly different number of cells in the tail (p-value<0.05). Conversely, at the same developmental stage, *pmela* was expressed in a significantly different number of cells on the surface fish yolk sac (p-value<0.05) and tail (p-value<0.01). This quantitative analysis of the developmental changes in pigment cell gene expression through *pmela* and *tyrp1b* allows for a better understanding of the mechanisms driving degenerative trait evolution in the extreme cave environment. This work was supported by a grant from the National Science Foundation (DEB-1457630) to JBG.

P1.181 SEDLMAYR, JC*; SCHACHNER, ER; KLEY , N; GIGNAC, PM; LSUHSC-SOM, Stony Brook School of Medicine , Oklahoma State Univ. Center for Health Sciences; *jsedlm@lsuhsc.edu*

Evidence of a Pineal Gland in Crocodylia

Among all vertebrates, crocodylians are thought to be unique in lacking a pineal gland. This is despite the possession of well-developed pineal glands in birds, their closest living sister group, and evidence for a pineal gland across extinct archosauriforms in the form of a pineal fossa or foramen. Crocodylians do, however, demonstrate a rhythmic melatonin cycle. Previously, we demonstrated that the crocodylian Harderian gland, as in other tetrapods including birds, forms part of a Harderian-retinal-hypothalamic axis (HaH) that rhythmically secretes melatonin along a circadian cycle. Crocodylians, as archosaurs, share with birds a similar secretory and immunological nature and a similar vascular network supplying and draining the Harderian gland. During our earlier studies we found gross and histological evidence of a follicular "pineal" gland in Alligator with pinealcytes similar in appearance to the follicular nature of the gland in basal birds. The use of iodine-enhanced micro-CT imaging has further evidenced a pineal gland in Alligator mississippiensis. We are currently conducting a more extensive analysis of this structure in other species of Crocodylia via micro-CT (Caiman crocodilus) and digitization (C. crocodilus and Crocodylus niloticus) using a digital capture station and specimens from the R. Glenn Northcutt Comparative Collection of Vertebrate Neuroanatomy and Embryology; this is part of a larger effort to create a comparative digital neuroanatomy database and atlas and demonstrates its vital use as a tool in the study of brain evolution.

P1.282 SEGALL, M*; HERREL, A; GODOY-DIANA, R; MNHN/ESPCI, MNHN, ESPCI; *marion.segall@live.fr*

Does morphological convergence of the head enhance prey capture performance in aquatically foraging snakes?

Underwater prey capture is a challenge for aquatic animals because of the high density and viscosity of water that impairs the movement of the predator and that can trigger the prey startle response. To circumvent these constraints, aquatic predators can adapt their morphology to be more streamlined. Snakes are an excellent model to assess whether these physical constraints have driven the evolution of their phenotypes as they have invaded both freshwater and marine environments. To circumvent the hydrodynamic constraints of prey capture underwater, previous studies suggested that the "ideal" head shape for an aquatic snake would be long and thin. In a recent publication, we demonstrated morphological convergence of head shape of aquatic snakes, but with a different pattern: aquatic species have more bulky and short head than the non-aquatic foragers. These results, although quite surprising, can make sense from a fluid mechanics point of view. Indeed, the physical constraints are directly related to the surface area that is facing the flow during the movement in addition to its shape. The aim of this new study is to assess whether this bulky and short head is more efficient to capture prey underwater. To do so, we use 3D-printed models of snake heads to measure the forces imposed on the different shapes during an impulsive motion that mimics an underwater strike. In addition, a force sensor was placed at the end of the strike arena to detect the magnitude of the pressure wave generated by the different shapes. Our results show that the force imparted upon the aquatic shape is indeed lower than the one recorded for the non-aquatic shape, meaning that having a thin and long head might not be as efficient as previously thought.

97.3 SEGRE, PS; DAKIN, R; READ, TJG; STRAW, AD; ALTSHULER, DL*; University of British Columbia, University of Freiburg; *doug@zoology.ubc.ca*

Mechanical constraints on flight at high elevation decrease maneuvering performance

High elevation habitats offer ecological advantages including reduced competition, predation, and parasitism. However, flying organisms at high elevation also face physiological challenges due to lower oxygen availability and air density. These constraints are expected to affect the flight maneuvers that are required to compete with rivals, capture prey, and evade threats. To test how individual maneuvering performance is affected by elevation, we measured the free flight maneuvers of male Anna's hummingbirds in a large chamber translocated to a high elevation site, and then measured their performance at low elevation. We used a multi-camera tracking system to identify thousands of maneuvers based on body position and orientation. At high elevation, the birds' translational velocities, accelerations, and rotational velocities were reduced, and they used less demanding turns. To determine how mechanical and metabolic constraints independently affect performance, we performed a second experiment to evaluate flight maneuvers in an airtight chamber infused with either normoxic heliox, to lower air density, or nitrogen, to lower oxygen availability. The hypodense treatment caused the birds to reduce their accelerations and rotational velocities, whereas the hypoxic treatment had no significant effect on maneuvering performance. Collectively, these experiments reveal how aerial maneuvering performance changes with elevation, demonstrating that as birds move up in elevation, air density constrains their maneuverability prior to any influence of oxygen availability. Our results support the hypothesis that changes in competitive ability at high elevations are the result of mechanical limits to flight performance.

P3.252 SEIDEL, R*; LYONS, K; BLUMER, M; ZASLANSKY, P; FRATZL, P; WEAVER, JC; DEAN, MN; MPIKG, Germany, CSULB, USA, MUI, Austria, Charité, Germany, Wyss Inst., USA; *ronald.seidel@mpikg.mpg.de*

Ultrastructural and Developmental Features of the Tessellated Endoskeleton of Elasmobranchs (Sharks and Rays)

Tesserae are minute, mineralized tiles covering the cartilaginous skeletons of elasmobranch fishes, linked to one another via flexible joints. Despite tesserae being a defining feature of these fishes, little is known about their development and 3-dimensional, ultrastructural organization, partly from the lack of standardization in sectioning plane, skeletal elements and species investigated. Our approach integrates histology, electron microscopy and synchrotron and laboratory µCT scans of ontogenetic series of round stingray *Urobatis halleri* skeletons, showing that the tessellated pattern commonly recognized in adult animals results from isolated mineralized platelets that appear early in development and grow toward one another until they collide to form a continuous tessellation. Backscatter electron microscopy reveals striking, formerly unrecognized patterns of mineral heterogeneity in tesserae, features of oscillating mineral density that likely contribute to structural reinforcement of the tissue. High-res CT data indicate that the joints between tesserae are far more structurally complex than previously believed, involving complicated arrangements of mineralized and fibrous materials, but no structural interdigitations. Inter-species comparisons reveal that despite large variation in tesseral shape and size, there are commonalities in tesseral features, especially in mineral density and cell distribution, suggesting universal principles of tesseral growth and form across elasmobranchs. We provide new insights into the development and function of this ancient tissue type, proposing a system of accretive growth and local inhibition to explain the tessellated pattern distinct to these fishes.

P2.55 SELCER, KW; Duquesne University, Pittsburgh, PA; *selcer@duq.edu*

Evolution of a disorganized protein region: variation in the phosvitin amino acid composition of avian vitellogenins.

The egg-yolk precursor vitellogenin (VTG) can be useful for studying evolutionary processes due to its crucial role in providing embryos of oviparous animals with energy and nutrients. Phosvitin, a segment of VTG, is characterized by many serine residues over a short span of amino acids. Little is known about the evolution of phosvitin. I performed analyses of the serine composition and gene codon usage of the phosvitin region of avian vitellogenins, using data from genome sequencing of over 30 bird species. Of the three avian VTGs, VTG1 has most serines, the major egg-yolk precursor VTG2 has fewer and VTG3 has the least. However, VTG2 shows the widest variation in serine number. Amino acid composition analysis revealed substantial variation in the number of charged residues among species, particularly lysine, and the number of charged residues was positively correlated with the number of serines. Codon usage analysis for serine revealed differences between vitellogenin and other proteins (e.g., ovalbumin and serum albumin) and among the VTG regions, with the phosvitin region favoring AGC and AGT. Most repetitive serine sequences in the phosvitin region used AGC for their codons. The downy woodpecker had the most serines in the phosvitin region of VTG2 and had a repeated sequence of SSSSSSK with a perfectly repeating codon sequence. There were 18 perfect repeats of this "mini-satellite". VTGs of many other bird species contained this sequence, but not all. The presence of multiple serine repeats, and their selective codon usage, are consistent with characteristics of a disorganized protein region. Triplet expansion (codon slippage), mainly of AGC, is likely the mechanism for generating the serine repeats in the phosvitin region of avian vitellogenins.

98.2 SELF, JD; COLLINS, CE*; MCBRAYER, LD; Georgia Southern Univ., Univ. of California, Riverside; *saxicoly@gmail.com*

Does bipedalism confer an advantage to lizards sprinting over obstacles?

Terrestrial animals evade predators and capture prey by running over uneven and highly variable terrain. Characterizing the mechanisms to traverse obstacles can clarify crucial aspects of how animals interact with their environment. Bipedal running may allow animals to move over obstacles faster relative to quadrupedal running or jumping. Evolving first as a consequence of acceleration, facultative bipedalism is known to be exploited in certain lizard lineages. However, the ecological advantages of bipedalism remain unclear. We tested the hypothesis that bipedalism is advantageous relative to quadrupedal running when traversing obstacles. Specifically, we quantified how sprint speed and kinematics changed when traversing an obstacle and if this varied with the use of a bipedal or quadrupedal posture. Data were quantified from high-speed video of four lizard species running down a 3m runway either with or without an obstacle. In general, bipedal obstacle negotiation was faster relative to quadrupedal strides. Furthermore, bipedal obstacle negotiation was equal to sprint speed attained on a flat surface. The tail was held at a depressed angle during obstacle negotiation, suggesting that tail function is essential in maintaining speed. We suggest that while bipedalism may not increase velocity on a level, straight trackway, it does confer a velocity advantage when negotiating difficult terrain by allowing the lizards to maintain a constant center of mass height, extending stride length, increasing efficiency, and allowing a line of sight beyond the obstacle.

P1.9 SELF DAVIES, ZT*; USHERWOOD, JR; The Royal Veterinary College, London; *zself@rvc.ac.uk*

Stepping into Science: engagement doesn't have to be a selfless act

There is an increasing drive from funding bodies, learned societies and policy makers for more researchers to engage and communicate with the public. While many agree that this is worthwhile, there are a number of barriers to engagement as well as a lack of agreement amongst researchers on how best to carry this out. One such barrier is finding the time to take away from teaching and research. In the field of biomechanics specifically, the task of explaining complex physics and mechanical modelling to a non-specialist or young audience is considerable. With regard to research, it is commonly a struggle to recruit a large cohort of human subjects, representative of the population. Here we demonstrate an engagement model which simultaneously acts as an opportunity for the collection of large datasets for scientific study. Key motivations of the project were to address gender disparities between scientific disciplines studied at university; to demonstrate the relevance of principles in maths, physics and engineering to biology, and to collect a large dataset of human walking kinetics. It is thought that active participation can increase enthusiasm, knowledge and retention and, when it comes to human basic and clinical research, engagement activities allow access to a large and varied population of experimental subjects. Here we present a novel approach to engagement and its integration with active research, demonstrating our methods for engaging children and members of the general public in the maths, physiology and mechanics of human walking, and report on our dataset.

127.6 SENNER, N.R.*; VELOTTA, J.P.; WOLF, C.J.; CHEVIRON, Z.A.; University of Montana; *nathan.senner@mso.umt.edu*

The Stress Response of Peromyscus Mice to Experimental High Elevation Conditions

Recent studies of populations inhabiting extreme environments have found contradictory results, with some observing reduced fecundity but little improvement in adult survival, and others failing to identify any evidence of higher fitness costs in extremophile populations. These contradictory findings suggest that evolutionary history and gene flow may strongly mediate the ability of populations to adapt to extreme environments. To test this hypothesis, we subjected six populations of *Peromyscus* mice to experimental elevational treatments — 1000, 3000, and 4500 m — in hypobaric chambers following acclimation to low elevation conditions. Our experiment included a mix of highland and lowland populations, with some of the highland populations coming from species with broad elevational distributions — suggesting the potential for ongoing gene flow across elevations — and others being strictly high elevation specialists. We measured the resting and summit metabolic rates, fecal corticosterone concentrations, and reactive oxygen species levels of individuals both before and after experimental treatments, with the expectation that all populations would exhibit heightened stress responses and reduced aerobic capacities at high elevations relative to lower elevations, but that strictly highland populations would show the smallest changes in stress levels and metabolic function. In combination with recent studies documenting the contributions of both flexible and canalized traits to observed extremophile phenotypes, our study suggests that inter-specific differences in both historical and contemporary demographic processes may help explain some of the life-history variation observed among these populations.

50.2 SEROTA, MW*; WILLIAMS, TD; Simon Fraser University, Simon Fraser University ; *mitchellserota@gmail.com*

Individual Variation in Activity Patterns of Chick-Rearing Birds Using an Automated Radio Telemetry System

Parental care (e.g. provisioning nestlings) is widely assumed to be costly, and life-history theory predicts that individuals that invest more in parental care should benefit in terms of number of offspring produced but that increased parental care might come at a cost in terms of decreased future fecundity and/or survival. However, the notion that parents that work "harder", commonly measured by the rate at which parents visit the nest box to provision their chicks, produce more, fitter chicks is surprisingly poorly supported. One potential reason for this apparent lack of relationship between measured work load during parental care and breeding productivity is that nest visit rate does not provide a good measure of foraging effort (even though this is the most commonly used metric). During chick-rearing, provisioning birds can adjust their foraging behavior in many other ways, e.g. varying load size, prey type, foraging distance, etc. Here, we investigated effects of handicapping (i.e. wing clipping) on parental effort during reproduction in breeding European starlings, *Sturnus vulgaris*. Using an automated radio telemetry system we tracked individual breeding females 24/7 for the entirety of the breeding period. Our data suggests that there is marked variation in daily activity patterns amongst individuals. We predict that individuals with an increased activity rate will bring back a greater proportion of their preferred prey type, Tipulidae larvae. Consequently, individuals with greater activity rates will have a greater productivity and overall chick quality. We also determine repeatability of variation in activity, comparing first and second breeding attempts, for several provisioning metrics (provisioning rate, activity level, load size, and prey type) and whether that individual variation explains breeding productivity.

38.5 SEROY, SK*; GRÜNBAUM, D; University of Washington; *sseroy@uw.edu*

Impacts of ocean acidification on growth and inducible defenses in a marine bryozoan

Calcifying organisms in marine systems are experiencing environmental changes due to ocean acidification (OA), an increased oceanic uptake of atmospheric CO_2. Previous studies have established that acidification often hinders calcification. However the potential of acidification to alter interactions between species is still poorly understood. The calcifying bryozoan, *Membranipora membranacea*, presents an informative model system to understand OA effects on species interactions. *Membranipora* rapidly forms defensive chitinous spines in the presence of the predatory nudibranch, *Corambe steinbergae*, which are effective in reducing predation. Spine formation is dependent on the growth of new calcified zooids. This project experimentally investigated effects of OA on bryozoan growth rates and nudibranch-induced spine formation in *Membranipora*. Bryozoan colonies were divided and cultured in ambient or low pH treatments, with or without nudibranch cue. OA impacts on growth, mortality and spine formation in *Membranipora* were assessed. The presence of nudibranchs reduced bryozoan growth rates in both ambient and low pH treatments. Contrary to hypothesized results, increased growth was observed in low pH treatments compared with ambient treatments. While there were general trends, there was also high variability among colony responses. Growth and mortality data were used to parameterize a size-structured partial differential equation model of bryozoan populations. The resulting model is an empirically-based representation of bryozoan growth, including predation and acidification effects, that scales up individual colony responses to population and community levels, and lends insight to how changes in inducible defenses under future oceanic conditions influence community dynamics.

47.2 SERVETNICK, M*; STEINWORTH , B; BABONIS, L; SIMMONS, D; SALINAS-SAAVEDRA, M; MARTINDALE , MQ; University of Washington Bothell , Whitney Marine Lab, University of Florida ; *mds56@uw.edu*

Cas9-mediated excision of brachyury in Nematostella vectensis disrupts development of the pharynx, organization of endoderm, and patterning of the oral-aboral axis

The mesoderm was a key novelty in animal evolution, though we understand little of how mesoderm arose. *brachyury*, the founding member of the T-box gene family, is a key gene in chordate mesoderm development, though the gene was present in the opisthokont ancestor, long before mesoderm appeared. To examine the role of *brachyury* in a sister-group to triploblasts, we excised the gene using CRISPR/Cas9 in the diploblastic cnidarian *Nematostella vectensis*. In these embryos, the pharynx fails to form, endoderm organization is aberrant, ectodermal cell polarity is disrupted, embryos fail to elongate along the oral-aboral axis and patterning along this axis is perturbed. Analysis of gene expression by both qPCR and *in situ* hybridization shows that many genes both in the same expression domain, as well as outside the domain, of *brachyury* are affected, including downregulation of most Wnt genes at the oral pole. It is likely that some, though not all, effects of *brachyury* are mediated by its effect on Wnt gene expression.

P1.245 SETH, D*; FLAMMANG, B; LAUDER, G; TANGORRA, J; Drexel University, New Jersey Institute of Technology, Harvard University; *ds663@drexel.edu*

Perturbation Studies to Investigate Compliance Modulations in the Caudal Fin of a Bluegill Sunfish

It has been hypothesized, using robotic models and some biological studies, that the fish actively stiffen their tail as the swimming speed increases. However, no such modulations have been confirmed by directly investigating the stiffness of the fin of a fish swimming freely at different speeds. In this study, the caudal fin of bluegill sunfish (N = 2) was perturbed with vortex rings, as the fish swam naturally at three different swimming speeds: slow speed at which the fin was stationary, medium speed at which the fin was flapping slowly (< 1 Hz), and high speed at which the fin was flapping at 1.5 Hz (body-caudal fin swimming). The stiffness modulations were studied by comparing the fin's deviations from natural swimming that were caused by a constant strength perturbation during different swimming speeds. The deflection in the caudal fin decreased when the swimming speed of the fish increased from the low to the medium or high speed, but did not change much when the swimming speed increased from the medium to high speed. In other words, the deflection did not drastically change with the flapping frequency of the fin. These results suggested that the fin stiffened when the caudal fin transitioned from being stationary to being flapped during swimming, but there was no consistent or strong evidence that the fin stiffened with an increase in speed, once the fin had begun flapping. This perturbation technique will be validated by perturbing flexible foils and ensuring that deviations caused by a perturbation are a reliable quantification to estimate stiffness changes in the fish fin. Additional experiments will be conducted with multiple fish swimming at the same range of swimming speeds.

69.7 SETTON, EVW*; SHARMA, PP; University of Wisconsin-Madison; *setton@wisc.edu*

Conservation of Sp6-9 Function in Patterning Prosomal Appendage Fate in the Spider Parasteatoda tepidariorum

The *Sp* family of zinc finger transcription factors is key to leg fate specification and leg outgrowth in both vertebrates and invertebrates. In the fruit fly *Drosophila melanogaster*, an *Sp6-9* homolog activates *Distal-less* and thus establishes ventral appendage fate, but the incidence and functions of *Sp* homologs in the subphyla Myriapoda and Chelicerata are unknown. We utilized available genomes and transcriptomes of myriapod and chelicerate exemplars and conducted a bioinformatic survey of *Sp* gene family members across Arthropoda. We included newly sequenced developmental transcriptomes for *Phalangium opilio* (harvestman), *Archegozetes longisetosus* (mite), and *Lithobius atkinsoni* (centipede) to identify orthologs of *Sp* genes at the base of the arthropod tree of life using phylogenetic analysis. To test the function of an *Sp6-9* ortholog in Chelicerata, we conducted parental RNA interference in the spider *Parasteatoda tepidariorum*. Here we show that the distribution of three *Sp* gene family members is typical across arthropods, with some losses of *Sp5* in unrelated lineages. We further show that knockdown of the spider *Sp6-9* ortholog results in truncation of all prosomal appendages and the loss of one body segment, consistent with a model of positive regulation of *Dll* by *Sp6-9* in this chelicerate species. Intriguingly, spinnerets, whose evolutionary origins are not clear, do not express *Sp6-9* during outgrowth, and their morphogenesis was not affected in the knockdown phenotypes. These data provide support of a conserved genetic mechanism for leg development across all arthropods, and separately suggest that specification of spinneret identity involves different mechanisms in comparison to walking legs.

44.4 SEWALL, KB*; DAVIES, S; Virginia Tech; *ksewall@vt.edu*

Neural activation in response to playback differs between urban and rural song sparrows

Urbanization is a critical environmental change that can impact endocrine function, physiology, and behavior of wild birds. Behavioral differences, particularly in territorial aggression, have been previously described in male song sparrows living in urban and rural habitats, with urban males behaving more aggressively to playback. Such behavioral differences must be underpinned by differences in the brain, yet little work has explored how urbanization and neural function may be interrelated. We explored the role of neural activation within a network of brain regions, collectively called the social behavior network, that regulates social behaviors, including territorial aggression. Specifically, we played free-living, territorial male song sparrows conspecific songs for 6-15 minutes, captured them, collected their brains, and measured an immediate early gene (Fos). We also collected a blood sample to measure circulating testosterone. We found that Fos immunoreactivity differed in rural and urban birds across several brain regions, including two regions specifically implicated in male territorial behavior (the lateral septum and bed nucleus of the striaterminalis) with rural males showing higher neural activation than urban males. This difference was not explained by the duration of playback, date or time of testing, or plasma testosterone. Though future work linking territorial behavior with patterns of neural activation in response to song playback is needed, these results implicate the social behavior network in regulating well-established differences in territorial behavior among song sparrows living in rural and urban habitats.

125.2 SHAH, AA*; GHALAMBOR, CK; SHAH, Alisha; Colorado State University; *alishas0624@gmail.com*

Does Climate Variability Predict Thermal Tolerance? A Comparison of Thermal Breadths in Aquatic Insects Across Elevation & Latitude

Climate variability has long been implicated in shaping the thermal breadths of organisms. In 1967, Daniel Janzen extended the climate variability hypothesis to include elevation gradients and suggested that increased temperature overlap across elevation on seasonally variable temperate mountains favors organisms with wider thermal breadths compared to organisms on thermally stable tropical mountains. Few studies have tested this hypothesis using standardized methods, and to our knowledge no studies have examined thermal tolerance patterns in aquatic systems, where fluctuations in temperature are reduced relative to air. To investigate how climate variability at a given site determines thermal tolerance, we first confirmed that stream temperatures at our temperate locality (Colorado Rocky mountains) have greater annual variation than streams at our tropical locality (Ecuadorian Andes mountains). We then measured thermal breadth in over 20 species of temperate and tropical aquatic insects by calculating the difference between the natural, un-manipulated critical thermal maximum and minimum limits. We found that temperate aquatic insects from the Rockies typically have wider thermal breadths (i.e. higher CTmax and lower CTmin values) compared to their tropical Andean relatives. Across elevation we detected a trend of narrower thermal breadths for temperate high elevation insects but wider thermal breadths for tropical high elevation insects. Our results indicate that climate variability may play an important role in shaping the thermal breadth of aquatic insects and may give insight into their vulnerability to climate warming.

P3.196 SHAKIR, R.G*; GRANELLO, M.E; SPEARS, D.C; MOORE, B.C; Sewanee, The University of the South; *shakirg0@sewanee.edu*

Assessing Alligator Phallic Collagen Architecture using Picrosirius Red Staining & Polarized Light Microscopy

Collagen fiber architecture plays important roles in maintaining tissue structure and influencing tissue function. In many male copulatory structures, collagen bundles contribute to the production of rigidity that allows intromission. Picrosirius red staining of histological tissues sections causes collagen fibers to emit birefringent light when viewed under a circularly polarized light microscope. We employed this simple and sensitive method to identify the collagen fiber architectures in American alligator (*Alligator mississippiensis* histological tissue sections. Collagen bundle thickness and orientations differed with phallic region. The collagen-dense phallic shaft displayed a basket weave of dense collagen, putatively imparting tensile rigidity necessary for intromission. In contrast, the distal glans containing spongiform inflatable regions showed regions of thick, dense bundles surrounding thinner, sparser bundles in the regions that engorges with blood during inflation. These results add insight to an understanding of the biomechanical properties of the alligator phallus. We hope to use this technique to understand phallic variation among crocodylians, identifying both conserved morphologies across species and species-specific phallic novelties, and to develop functional hypotheses incorporating the gross spatial relationships of reproductive tissues and detailed extracellular matrix characteristics.

134.1 SHANKAR, A*; CANEPA, JR; GRAHAM, CH; WETHINGTON, SM; POWERS, DR; Stony Brook University, George Fox University, Hummingbird Monitoring Network, Stony Brook University; WSL Zurich; *nushiamme@gmail.com*

Energy Budgeting in a Temperate Hummingbird

Warming climates will likely cause organisms to adjust their energy budgets to accommodate temperature-related changes in direct (e.g. thermoregulatory) and indirect (e.g. foraging, flying) costs. Our goal is to determine which aspects of the daily energy budget (e.g. thermoregulation, daytime activity costs, nighttime costs) change in response to environmental variation. This will help us understand the strategies species might use to balance their energy budget over the short term to survive environmental extremes. Energy-budget management is particular challenging for hummingbirds because they have high metabolic rates and store little fat. The lack of significant energy storage by hummingbirds makes their energy budget relatively simple compared to other endothermic systems. We modeled energy budgets for two populations of broad-billed hummingbirds (*Cynanthus latirostris*) that vary significantly in their daily energy expenditure and live in habitats with different thermal profiles, topography, and vegetative structure. Our analyses show that the difference in daily energy expenditure was due primarily to thermoregulatory costs. High thermoregulatory costs appear to be balanced by a decrease in activity and concurrent use of more favorable microclimates. Decreased activity could reduce foraging and social interactions resulting in differential fitness across sites.

P3.63 SHANNON, MC*; BUTLER, JM; MARUSKA, KP; Louisiana State University; *jbutl48@lsu.edu*

Coping strategies change over time during repeated social defeat in an African cichlid fish

Dominance hierarchies resulting from repeated social interactions are common across the animal kingdom and have important consequences for reproduction and survival. Animals of lower social status cope with repeated social defeat using a variety of ‘active' and ‘passive' strategies. However, there remains a paucity of information on how an individual's coping strategy changes over time or where this behavioral change may be controlled in the brain. We used a resident-intruder paradigm in the African cichlid fish *Astatotilapia burtoni* to investigate the neural correlates of repeated social defeat to the same aggressor, which better reflects the natural behavioral ecology of this lek-dwelling fish. We quantified aggressive behaviors performed by the resident, the intruder's response (flee, hide, search, or no movement) to each behavior, and the amount of time the intruder spent ‘hiding' or ‘searching' for an escape, and then classified intruder behaviors as either passive or active using a principle component analysis. Passive (hiding, no attempt to flee, no aggressive behaviors performed) and active (searching, fleeing behaviors) coping behaviors were performed by all fish, and the individual variability in coping strategy depended on resident aggression. Despite this variability, all individuals increased their use of active coping on day 3 of repeated social defeat. To examine the neural correlates of this behavioral switch on day 3, we are quantifying immediate early gene expression in nuclei of the social decision-making network of animals collected on days 2, 3, and 4 of repeated social defeat. While variability in coping strategy is well documented, this is the first study to demonstrate temporal changes in coping mechanisms associated with social defeat in fishes and could reflect learned helplessness.

P2.217 SHANNON, RP*; BOLEK, MG; Oklahoma State University; *shannrp@okstate.edu*
Blood Parasites of the Herpetofauna from the Great Plains of the United States
Compared to the blood parasites of mammals and avian hosts, relatively little information is available about the host specificity, prevalence and distribution of blood parasites infecting amphibians and non-avian reptiles. The few available surveys suggest that amphibians and reptiles are commonly infected with a diverse group of blood parasite species including hemoflagellates and apicomplexans. However, currently no information is available on the geographic distribution and host specificity of blood parasite species in amphibian and reptile hosts from the Great Plains region of the United States. To investigate the blood parasites infecting the herpetofauna of Oklahoma, USA, 6 locations in north central Oklahoma and 1 location in southeastern Oklahoma were surveyed for amphibians and reptiles. Over 3 field seasons during 2014 to 2016, 295 amphibians from 6 families and 19 species, and 4 reptiles from 3 families were collected and examined for blood protozoa. A total of 11 blood protozoan species/morphotypes were identified using morphological and/or molecular techniques. In amphibian hosts, 5 species/morphotypes of *Trypanosoma* and 1 species of *Hepatozoon* were found infecting the family Ranidae, and 3 species/morphotypes of *Trypanosoma* were found infecting the family Hylidae. Interestingly, individual amphibians were often infected with multiple species/morphotypes of blood parasites. In addition to the amphibian hosts, 1 species of *Haemogregarina* was found infecting the red-eared slider, *Trachemys scripta elegans*, and 1 species of *Hepatozoon* was found infecting the diamondback water snake, *Nerodia rhombifer*. This work provides critical data on the diversity, host use, and geographic distribution of blood parasites of amphibians and reptiles from the Great Plains and a starting point for investigations on the biology and ecology of these understudied parasites.

S7.4 SHARMA, PP; University of Wisconsin-Madison; *prashant.sharma@wisc.edu*
Chelicerate genomes, chelate appendages, and conquering land: a view of arachnid origins through an evo-devo spyglass
The internal phylogeny of Chelicerata and the attendant evolutionary scenario of arachnid terrestrialization have a long and contentious history. Datasets of morphologists and paleontologists typically recover scorpions close to the base of the arachnid tree of life, whereas recent phylogenomic analyses have recovered support for a clade comprised of scorpions and tetrapulmonates (i.e., Arachnopulmonata), implying a single origin of the arachnid book lung. To adjudicate between these competing hypotheses with an independent data class, I examined the composition of euchelicerate genomes, using mandibulate genomes for comparison. Here I show that a partial or whole genome duplication event is shared by arachnopulmonates, to the exclusion of apulmonate arachnids. These data imply a single, derived origin of the arachnid book lung at the base of Arachnopulmonata. To investigate the developmental origins of book lungs, I compare the developmental genetic basis for respiratory system development in insects and arachnids. I examined the development of respiratory primordia in a scorpion, a harvestman, and a spider. Here I show that the respiratory primordia of arachnids are not positionally homologous to those of insects, as they occur within the posterior region of the embryonic parasegment; in *D. melanogaster*, tracheal placodes occur anterior of this region. I further demonstrate that candidate genes critical to tracheal fate specification in *D. melanogaster* are expressed very differently in all three arachnid exemplars. Taken together, these data suggest that mechanisms of respiratory system development are not homologous in insects and arachnids, and that different terrestrial lineages have solved the challenge of aerial respiration using different developmental mechanisms.

S10.3 SHARPE, J.; Centre for Genomic Regulation, Barcelona; *james.sharpe@crg.eu*
Changing while staying the same: Self-organized patterning allows a deeply-conserved gene circuit to produce varying skeletal arrangements during limb evolution.
The limb has been a classical system for asking questions about evolution and development. It has long been proposed that digit specification was the result of a self-organizing periodic patterning process (Ede & Law, Journal of Theoretical Biology, 1975) - and maybe even a Turing system (Frisch & Newman, Science, 1979). However, evidence for the molecular basis of this pattern has been hard to obtain. Over the last few years we uncovered evidence for the involvement of Hox genes and FGF signaling as key modulators of this process (Sheth et al. Science, 2012), and for Bmp and Wnt signaling to constitute the Turing system itself (Raspopovic et al. Science, 2014). Most recently, we have shown that the same core regulatory circuit is also involved in the patterning of radials in the catshark Scyliorhinus canicula (Onimaru et al. Nature Communications, 2016). Through computer simulations of realistic growing models of the mouse limb bud and the catshark fin bud, we illustrate how this single regulatory circuit can recapitulate the distal skeletal patterns of both species. These data-driven models strengthen previous theoretical proposals that limb skeletal patterns were probably quite flexible during evolution. Fundamental to this flexibility is the self-organising nature of the patterning process. It supports the view that comparing the details of skeletal arrangement across species provides only limited information about evolutionary relationships.

S9.5 SHEEHAN, Michael J; Cornell University; *msheehan@cornell.edu*
Not all partners are equal: A role for identity signaling in generating differential cooperative behavior.
The evolution of stable cooperation requires discrimination among potential recipients - either those with shared genotypes or also show cooperative behavior. Discrimination requires diversity in appearance, smell or vocalizations within a population. Thus, the mechanisms that maintain diversity in traits used for recognition are central to understanding the maintenance of costly cooperative behaviors. Paradoxically, models of recognition trait evolution have argued that cooperation leads to positive frequency-dependent selection and the loss of diversity in recognition traits, eroding cooperation. As a result, authors have appealed to balancing selection on traits for reasons other than recognition (e.g. immune selection on MHC) to explain the maintenance of recognition. Here, I challenge this view by first presenting evidence that recognition traits used to mediate cooperation are themselves under negative frequency-dependent selection as a result of social interactions. Second, I present a novel model showing that learning recognition templates is sufficient to maintain diversity in recognition traits used for cooperation. Importantly, this model predicts a positive feedback whereby cooperation maintains diversity, which in turn favors higher investment in cooperation, leading to greater diversity, etc.

S4.4 SHELDON, K.S.; University of Tennessee, Knoxville; *ksheldon@utk.edu*

The impact of temperature variation on physiology and distributions of tropical and temperate ectotherms

Differences in environmental temperatures can influence organismal physiology and biogeography, with large consequences for ecology, evolution and our understanding of the impacts of climate warming. Based on the seasonality hypothesis, smaller annual temperature variation in the tropics should result in reduced thermal tolerance, dispersal capacity, and elevational range sizes of tropical species compared with temperate species. Using beetles and *Liolaemus* lizards separated by latitude, I explored links between seasonality in temperature, physiology, and elevational range size. Thermal tolerance and elevational range size of beetles increased with increasing annual seasonality. Realized seasonality - the temperature variation restricted to the months that species are active - was a better predictor of both thermal tolerance and elevational range size of beetles than was annual seasonality. Additionally, beetles with narrower thermal tolerance had smaller elevational ranges. In *Liolaemus* lizards, annual seasonality was a good predictor of elevational range size. However, contrary to the seasonality hypothesis, thermal tolerance of adult *Liolaemus* was not a good predictor of elevational range size. In the case of *Liolaemus* lizards, temperature effects on reproduction and ontogeny may play a larger role in setting elevational distributions than the thermal tolerance of adults. These results support a mechanistic framework that links variation in temperature to the physiology and distributions of tropical and temperate ectotherms.

97.4 SHEPARD, ELC; WILLIAMSON, CJ*; WINDSOR, SP; Univ. of Bristol, Bristol, UK, Univ. of Swansea, Swansea, UK; *cara.williamson@bristol.ac.uk*

Adaptive Flight Behaviour Found in Urban Gulls using Orographic Lift

Birds are known to exploit global airflows; adapting their migratory routes to reduce the high energy costs associated with long distance flight. It would follow that birds also modulate their flight behavior at fine scales as well, however due to the stochastic nature of the fine scale environment these behaviors remain unknown. We investigated the flight behaviors of herring gulls (Larus argentatus) and lesser black-backed gulls (L. fuscus) in Swansea Bay, UK, where these gulls are often seen commuting along the urbanized seafront. There was significantly more gull traffic on days where wind conditions generated orographic lift in front of a row of three story hotels. The gulls were clearly exploiting the airflows around these seafront buildings so, in order to understand the aerodynamics involved we developed a model of the wind field in which the gulls were flying. The fine scale wind model of the urbanized beach was developed using computational fluid dynamics (CFD). When we added the flight trajectories to the wind model not only did we discover that gulls indeed change their flight paths to make use of the available wind energy, we also found adaptive flight strategies within this. The strategy appears to result in a self-regulating control phenomenon where gusts have a reduced effect on the bird's airspeed. We hypothesis that this behavior improves flight control in turbulent conditions and mitigates the risk of collision in a cluttered cityscape. Overall this study shows that gulls adaptively modulate their flight paths in relation to fine scale wind features created by urban development and opens up questions as to how birds utilize other fine scale wind flows.

P2.245 SHEPHERD, HS; New College of Florida; *hannah.shepherd13@ncf.edu*

Differential expression of two Ciona intestinalis V-type proton ATPase isoforms in acidic conditions

The impact of ocean acidification due to increased greenhouse gas emissions on ecosystems and the organisms which they are comprised of can be devastating. At the cellular level, pH changes can be dealt with in a number of ways, one of which is by the use of membrane bound proton pumps. This study focuses on the changes in expression of a V-type proton ATPase found in *Ciona intestinalis*. This species was chosen because it is widespread in marine habitats globally, and because it has been researched extensively for the effects of other marine pollutants. The objective of this experiment is to investigate how *Ciona intestinalis* expresses V-type proton ATPase genes to cope with acidic conditions. The *C. intestinalis* genome contains several proton ATPase subunit isoforms, and two isoforms for subunit A will be tested. The hypothesis is that the two isoforms will be expressed in different situations and different parts of the organism depending on the acidity of the environment. The tunicates will be kept in filtered seawater and fed a combination of dry Spirulina and Phytoplex. To begin, samples of *C. intestinalis* will be collected, frozen using liquid nitrogen, crushed into powder, and stored at -80^{o}. One set of samples will be collected before the addition of the acid, and several will be collected afterwards at 48, 72, 96, and 120 hours. RNA isolation and RT-PCR methods will be repeated for all samples. The mRNA will be isolated using RNeasy Mini Kit and reverse transcribed using Superscript II RT. The primer sets created for the two genes of interest and one house keeping gene (actin) will be used to run RT-PCR on the cDNA library. After these experiments have been completed, fluorescent ISH will be used to determine if the genes are expressed differently in different parts of the organism. The FISH will be performed on the whole organism without dissecting it in order to visualize the organs better.

131.8 SHERIFF, MJ*; MACLEOD, K; KREBS, CJ; BOONSTRA, R; Penn State University, University of British Columbia, University of Toronto; *mjs72@psu.edu*

The Lethality of Non-Consumptive Predation Risk

Predators play a critical role in shaping ecosystems, driving both population and community dynamics. Traditionally, studies have focused on the direct effects of predators, namely the killing of prey. However, more recently, non-consumptive, risk effects of predators on prey are being appreciated. The risk of predation can induce morphological and behavioral trait changes in prey that are physiologically mediated, and often come at a cost to reproduction and survival. Previously, we provided the first evidence in a free-living mammal, snowshoe hares, that risk-induced maternal stress lowers reproduction and compromises the offspring's stress axis (HPA-axis). Here we experimentally tested whether the risk of predation, acting via the stress axis, decreased survival of captively-held, wild hares. We exposed pregnant snowshoe hares to a live simulated predator (a trained dog that was not allowed to physically contact hares) for 1min every other day until parturition, and monitored survival of both mothers and offspring through to weaning. We found that females exposed to greater predation risk had higher stress hormone levels and greater mortality than control females. Further, we found that both pre-natal and post-natal mortality of offspring was higher even though risk exposure ceased at parturition, i.e., greater occurrence of abortion or stillbirth and higher mortality of viable offspring to weaning. Our results show, for the first time in a wild mammal, that in addition to direct killing, predators can increase the mortality of prey simply through risk effects. These findings have large implications to our understanding of predator-prey interactions and the influence of predators on population and community dynamics.

BART.1 SHERIFF, Michael; Penn State Univ.; *mjs72@psu.edu*
Integrating physiology, behavior, and ecology to understand the mechanisms that regulate and limit animal populations
George A. Bartholomew championed the idea of a unified biology and a hierarchy of biological explanations. In 1964, he stated that '...each level [of biology] finds its explanation of mechanism at levels below, and its significance at levels above.' He operated at the intersection of physiology, behavior, and ecology, appreciating that an organism is inseparable from its environment. Thus an animal cannot be understood without a deep knowledge of the world it lives in and has evolved from. My research implicitly stands on this foundation, addressing one of the fundamental questions in population ecology: what limits and regulates animal populations? In the past, population studies often treated animals as black boxes. However, their physiology is key to understanding how they integrate, respond to, and are changed by their biotic and abiotic environment. My approach is to bridge physiology, behavior, and ecology to understand the forces that shape individuals and, thus, impact their populations and communities. In this lecture, I will examine three species and their solutions to three ecological problems. First, arctic ground squirrels hibernate in one of most challenging environments and I will examine how climate-induced changes in snow cover may have population level consequences; second, snowshoe hare populations in the boreal forest go through predator-driven 10-year cycles and I will examine how the risk of predation influences maternal stress and may impact population demography and community processes; third, fence lizards in Alabama are contending with life-threatening invasive fire ants and I will examine how they are coping with and responding to this novel stressor. My research will stress the critical need to take laboratory-based physiology into the real world and thus ground our research within an ecological and evolutionary context.

32.6 SHINE, CL*; MCGOWAN, CP; University of Idaho; *shin0453@vandals.uidaho.edu*
Black bear (Ursus americanus) gaits and ground reaction forces: a comparison to grizzly bears
There has been limited biomechanical research on plantigrade species, despite the fact that this posture is ancestral and retained in many species. Within Carnivora, eleven of fourteen families are plantigrade or semi-plantigrade. Bears (family Ursidae) are a group of large, quadrupedal, plantigrade animals, which makes them unique. Our previous work has demonstrated some interesting characteristics of locomotion in grizzly bears. The aim of this study was to identify which, if any, of these characteristics were present in other bear species. Black bears live in similar habitats to grizzly bears and therefore may demonstrate some of the same locomotor patterns. We collected data from three captive adult male black bears. Preliminary results suggest that there are similarities between black bear and grizzly bear locomotion, but some of the unusual results from the grizzly bears are not present in the black bears. The vertical force traces were similar for both species, with a greater rate of force development in the hind limbs. Both species also used a transverse walk at slow speeds. The gait used at intermediate speeds differs between the two species; grizzly bears use a running walk, while the black bears appeared to use a pace. Grizzly bears produced relatively high lateral forces during locomotion, up to 13% of the vertical force. In the black bears this value is below 6%, which suggests they are not using their limbs for propulsion in the same way. Overall, our preliminary results suggest that the unusual aspects of grizzly bear locomotion are not shared by black bears, and therefore data need to be collected from more species to understand Ursidae biomechanics.

31.5 SHISHIDO, CM*; LANE, SJ; WOODS, HA; TOBALSKE, BW; MORAN, AL; Univ. of Hawaii at Manoa, Univ. of Montana, Missoula; *csmariko@hawaii.edu*
Temperature, body size, and righting ability of Antarctic pycnogonids
The challenge of understanding how organisms will respond to global climate change is especially important in Antarctica where species have evolved for millions of years in a cold and thermally stable environment. In Antarctica, the combination of cold and highly oxygenated waters are thought to have allowed many benthic marine invertebrates to reach unusually large body sizes. However, if large body sizes are only viable in a context of stable high oxygen, cold temperatures, and correspondingly low organismal metabolic oxygen demand, polar giants may be disproportionately sensitive to warming temperatures. To test this hypothesis, we are investigating the interactions between temperature, size, and performance (measured as righting ability) in a family of Antarctic sea spiders (Pycnogonida, Colossendeidae). Individual sea spiders were tested for continuous righting ability at three temperatures (-1.8, 4, and 9 °C) and performance was measured as number of flips per hour. We used sea spiders with body masses (wet weight) ranging 0.21 to 15.17 g. In all size classes, performance at 4 °C did not differ from ambient (-1.8 °C) but performance significantly declined at 9 °C. However, large-bodied pycnogonids did not appear to be disproportionately affected by the high temperatures. Our research is continuing during the Antarctic spring, 2016. NSF PLR- 1341485.

P2.60 SHOEMAKER, AK; SETTON, EVW*; SHARMA, PP; University of Wisconsin-Madison; *kenji.shoemaker@gmail.com*
Differential expression of dachshund in epipod and telopod derivatives suggests non-homology of crustacean gills and spider spinnerets
The ancestral, polyramous arthropod appendage is comprised of three components: epipod, exopod, and telopod. The telopod has been homologized to the walking legs of all modern arthropods, whereas epipods have been proposed to have given rise to insect wings, crustacean gills, horseshoe crab book gills, spider book lungs, and spider spinnerets. To test this homology statement, we compared embryonic gene expression of the proximal-distal (PD) axis patterning gene *dachshund* (*dac*) in the polyramous appendage of the amphipod crustacean *Parhyale hawaiensis* and the *dac-1* homolog in the spider *Parasteatoda tepidariorum*. Specifically, we aimed to investigate whether *dac* expression was conserved in the *bona fide* epipods of *P. hawaiensis* and its putative epipodal homolog, the spider spinneret. Here we show that canonical *dac* expression is observed in structures of telopodal origin, such as the pereopods of *P. hawaiensis* walking legs, and the pedipalps and walking legs of the spider. We did not observe *dac* expression in the developing epipods or exopods of *P. hawaiensis*. By contrast, expression of the spider *dac* homolog in the spinneret strongly resembles the expression pattern observed in the walking legs of *P. tepidariorum* and the pereopods of *P. hawaiensis*. Together with other characteristics of spinnerets, such as internal muscle attachment sites and the incidence of proximo-distal segmentation of spinnerets in basal spiders, these data suggest that spinnerets are not homologous to crustacean gills, but rather to arthropod walking legs. Our data thus counter the notion that spinnerets have an epipodal or gill-like origin.

8.1 SHPAK, N*; KATZIR, L; MENTEL, O; SHAVIT, K; MANOR, R; WEIL, S; AFLALO, ED; SAGI, A; Ben-Gurion University of the Negev, Beer-Sheva, Israel; *nirshpak@gmail.com*

Gene Knockdown and dsRNA Length in Crustaceans

RNAi utilizes cell auto-immune defense mechanisms against viruses. Complete sex reversal is achievable in freshwater prawn, *Macrobrachium rosenbergii* males by knocking down the transcript level of *M. rosenbergii* insulin-like androgenic gland hormone (Mr-IAG) through RNAi. The current method employs dsRNA comprising the entire *Mr-IAG* ORF sequence (518bp) injected to young genetic males. In the present study, the viability of dsRNA fragments which are shorter than the entire ORF was tested. A correlation between knockdown success and dsRNA length was detected. As longer the dsRNA, the lower *Mr-IAG* transcription was observed, while the entire ORF caused up to ~99% reduction in transcript levels. These results evoked the need to understand the cellular mechanism behind *Mr-IAG* knockdown. Thus, genes from the Dicer and Argonaute families associated with three knockdown pathways (siRNA, miRNA and piRNA) and *SID-1*, known as dsRNA passive channel, were mined from our *M. rosenbergii* transcriptomic library. Mining was done based on orthologues from related species validated by full sequencing. Our results suggest that *Mr-IAG* knockdown is mediated by the siRNA pathway since only *Dicer-2*, and *Argonaute-2* transcription levels were influenced by ds*Mr-IAG* administration. SID-1 function was verified by demonstrating an increase in its transcript level only in the presence of dsRNA. Positive correlation was demonstrated between higher *SID-1* and *Dicer-2* transcript levels, and longer dsRNA fragments. These results provide evidence for the systemic effect of dsRNA length on cellular immune response in crustaceans.

P3.113 SHUKLA, D*; CARRUTH, LL; WILCZYNSKI, W; Georgia State University; *dshukla3@student.gsu.edu*

Effects of social status on muscle glycogen content and fat storage in green anole lizards.

Male anoles form stable dominant-subordinate dyads when paired together under conditions of limited resources. After acquisition of their respective social status, dominants and subordinates show distinct behavioral profiles including quantitative differences in aggression and courtship as well as distinct endocrine patterns including changes in testosterone and catecholamine levels. Such widespread changes suggest that acquisition and maintenance of social status is accompanied by a change in the metabolic state as well. Hence, we evaluated differences in energy storage after acquisition of social status by measuring skeletal muscle glycogen levels and whole body fat level. Skeletal muscle tissue was obtained from size and weight matched male anoles paired for 11 days. Glycogen levels were then quantified by hydrolysis into glucose followed by colorimetric quantification of glucose levels. Muscle glycogen content was higher in established dominants relative to subordinates (paired t test: $t=2.504$, $p= 0.0336$) . Body composition was measured in live animals before and after pairing (9 days) using EchoMRI™, which utilizes nuclear magnetic resonance to distinguish body fat from lean mass. Dominants were found to have higher levels of body fat relative to subordinates ($t=2.235$, $p= 0.042$) after but not before pairing. Thus, changes in body fat levels accompany changes in social status. The difference in social status is also correlated with differences in muscle glycogen levels, but our results cannot determine whether this difference exists before pairing or acquired as a result of social status acquisition.

130.1 SHUMAN, JL*; COUGHLIN, DJ; Widener University; *jshuman@mail.widener.edu*

Thermal Acclimation and Red Muscle Function in Rainbow Smelt, Osmerus mordax, and Rainbow Trout, Oncorhynchus mykiss

Climate change is affecting the thermal environment of aquatic organisms. This work explores how changes in the thermal environment affect rainbow smelt (*Osmerus mordax*), a eurythermal species that experiences a wide range of temperature, and rainbow trout (*Oncorhynchus mykiss*), a stenothermal species that experiences a limited range of environmental temperatures and is more sensitive to changes in environmental temperature. Smelt were thermally acclimated to either a warm (10ºC) or cold (5ºC) temperature. Swimming performance in warm vs. cold acclimated smelt was tested and a video analysis of the swimming was examined to determine average tailbeat frequency. It was determined that the cold acclimated smelt had a faster maximum steady swimming speed and swam with a higher tailbeat frequency than the warm acclimated smelt. Muscle mechanics experiments demonstrated faster contractile properties in the cold acclimated smelt. Trout were thermally acclimated to 15ºC, 10ºC, or 5ºC. Data will be presented on thermal acclimation, swimming performance, and muscle physiology and how it compares between the rainbow smelt and rainbow trout. I predict that in both the smelt and trout, cold acclimated (CA) fish will have faster swimming abilities along with faster contractile rates in their red muscle. Additionally, I expect that the smelt will have a more pronounced thermal acclimation response.

P2.94 SHYAMAL, S*; GURUACHARYA, A; DAS, S; MYKLES, DL; DURICA, DS; Univ. of Oklahoma, OK, Colorado State University, CO, Colorado State University, CO; *shyamal@ou.edu*

A transcriptomic approach examining crustacean Y Organ molt cycle regulation via the mTOR signaling pathway

Crustacean molting is regulated by the interplay between inhibitory neuropeptides (MIH) secreted by the X organ located in the eyestalk (ES) and steroid hormones synthesized by the Y organ (YO). During intermolt, the YO maintains a basal state characterized by low ecdysteroid and high MIH titers. During early premolt, the YO transitions to an activated state characterized by a reduction in MIH titer, but retention of MIH sensitivity. mTOR signaling pathway genes are up regulated in early premolt- while rapamycin- which blocks mTOR signaling, has been shown to inhibit YO ecdysteriodogenesis. In *G. lateralis*, molt cycle entry was induced by eyestalk ablation (ESA). ESA animals were injected with either a single dose of rapamycin or DMSO carrier. Animals with intact eyestalks were examined as an intermolt control. YO tissue samples were harvested at 1, 3, and 7 days post-ESA and processed for RNA-seq on the Illumina platform. 224,631 contigs were obtained via Trinity de novo assembly; 31.92% of these could be assigned a SwissProt annotation. 51,408 differentially expressed genes (DEG) were identified using EdgeR with a 0.05 FDR cut-off. Rapamycin inhibits mTOR by complexing with FKBP12. DEG analysis revealed increased FKBP12 expression levels following rapamycin injection, with levels highest at day 7. A progressive decrease in the expression of mTOR pathway genes Akt, Rheb, EF2, S6K and PDK1 was observed, with Rheb and S6K showing minimal expression by day 7. Ecdysteroid pathway gene expression showed depressed levels relative to the DMSO datasets. A further detailed gene enrichment analysis is also in progress to evaluate DGEs downstream of the mTOR pathway. Supported by NSF (IOS-1257732).

P1.38 SIEBELS, AA*; CHILDS, AM; AFFUL, DK; SCHMIDT, JX; CLELAND, CL; James Madison University; *rosecs@jmu.edu*

Looming stimuli evoke a turning escape response that is mediated by both cerci and vision in crickets

In crickets, wind evokes an escape response, in which the cricket turns and then runs or jumps away. Previous results indicated that crickets largely utilize the same turning strategy when escaping looming stimuli. In contrast to wind stimuli, looming objects create both wind and visual sensory cues. However, the relative contributions of the two sensory cues and the receptor modalities - cerci, eyes, antennae, and body mechanoreceptors - to the escape response are unclear. The specific aim of our research was to identify the contribution of each receptor modality to the escape. A high speed camera captured the escape response of crickets (*Acheta domesticus*) to a 3" black polyurethane ball propelled to the cricket at a 45 degree angle. We designed a series of behavioral lesion experiments to determine if each of the four modalities were necessary or sufficient to produce an escape response. Based on 106 crickets, both cerci and eyes, but neither antennae nor body mechanoreceptors, contributed to the escape response. Eyes were necessary and sufficient for anterior looming stimuli, while cerci were necessary and sufficient for posterior looming stimuli. Although cerci have been considered the primary determinant of the escape response, vision may play a significant role, especially for anterior looming stimuli.

58.2 SIEBERT, S*; CAZET, J; JULIANO, CE; Univ. of California, Davis; *ssiebert@ucdavis.edu*

Piwi-piRNA Pathway Function in Somatic Stem Cells of Hydra

PIWI proteins are central players in a RNA regulatory pathway that is largely specific to the germ line and stem cells. The function of the PIWI-piRNA pathway and the identity of the pathway target genes in stem cells is, however, not well understood. Here we study the function of the *Hydra* PIWI homolog Hywi in stem cell maintenance within somatic stem cells. Knocking down *hywi* in *Hydra* epithelial stem cells is lethal. RNA-seq and differential gene expression analysis comparing transcript levels between 4-day old *hywi* RNAi juveniles and age-matched wild type siblings indicates that the PIWI-piRNA pathway represses RNA expression in these stem cells. Tissue and lineage specific RNAseq reveals that a significant fraction of the upregulated genes in RNAi animals are expressed within the differentiated cells of wild type animals. These findings lend support to the hypothesis that Hywi is required to maintain somatic stem cells by repressing differentiation genes. Furthermore, the upregulated genes include many that have been identified as injury response genes in regeneration studies. This suggests that Hywi acts upstream of a gene set that is activated during cell differentiation in wild type animals and that can be ectopically triggered by regeneration cues.

P2.257 SIFUENTES, I*; TEZAK , B; MILTON, SL; WYNEKEN, J; Florida Atlantic University; *fau.iromero@fau.edu*

Sex determination in turtles: is moisture playing a role?

Experimental studies with turtles known to have temperature-dependent sex determination (TSD), a form of environmental sex determination, suggest that moisture conditions during incubation may influence development and sex determination. Wetter substrates produce more males, whereas drier substrates produce more females. These results are consistent with findings in the field that sex ratios obtained from Loggerhead turtle (*Caretta caretta*) nesting beaches show a poor relationship with temperatures recorded *in situ* and more males were found in wetter years. When the relative moisture levels are considered with nest temperatures, sex ratio trends become more predictable. In this study, we used the freshwater turtle *Trachemys scripta* to test the effect of moisture on (i) embryonic growth (ii) sex ratio and (iii) gene expression and methylation patterns of two important sex determining genes, *Sox9* and aromatase. We found an effect of incubation moisture on the embryonic development reflected in growth rate and sex ratio. Gene expression analysis showed a dimorphic expression pattern between males and females of aromatase and *Sox9*, where the first was expressed only in females and the latter only in male gonads. Furthermore, we found a sex-specific methylation pattern in the aromatase promoter that is consistent with the expression patterns. To our knowledge, this is the first study to address the effect of moisture at genetic and epigenetic levels in systems active during TSD.

30.3 SIGWART, JD; Univ. of California, Berkeley; *j.sigwart@berkeley.edu*

Are rapid radiations doing something better, or is it just luck?

The evolutionary "success" of a genus is considered nearly synonymous with its species richness. Many animal taxa that contain rapid evolutionary radiations-- cichlid fishes in African Great lakes, *Anolis* lizards on Caribbean islands, cone snails-- have been the focus of theory-driven work in evolutionary biology. On the other hand, the preponderance of genera contain one or very few species. Many studies have noticed this, and suggested that there was some selective bias favouring lineages that have already survived the extinction that wiped out their nearest relatives. There are therefore seemingly contradictory hypotheses about general mechanisms in evolution: the potential selective bias for some heritable traits that either lead to adaptive radiations, or lead to the success of isolated monotypic lineages. An alternative hypothesis is that diversification, at global scales, is a dispassionate stochastic process. In terms of species richness, there are a large number of very small genera, and a small number of large genera, worldwide, in all animal groups. This size-frequency of genera in the real-world, agrees with predictions from very straightforward models of species-level evolution. The fact that there are predictable patterns in taxonomy that can be deduced from the mathematics of phylogeny, provides an important step forward to understand the mechanisms of selection and diversification.

95.4 SIGWART, JD*; SUMNER-ROONEY, LH; RAHMAN, IA; PARKINSON, DY; Univ. of California, Berkeley, Museum für Naturkunde, Berlin, Oxford University Museum of Natural History, Lawrence Berkeley National Laboratory; *j.sigwart@berkeley.edu*
Like a hole in the head (valve)
Sensory systems in animals with hard parts often require penetration of nerves through the skeleton: nerves penetrate bone in vertebrates, brachiopods have shell pores called punctae, and arthropod exoskeletons bear innervated sensilla. Polyplacophoran molluscs, or chitons, have "aesthetes", photosensory pores in their shells. Chitons have a distinctive armature of eight articulating calcareous shells that cover their dorsal body surface. In all living species, the eight shell valves are covered by a dense array of aesthetes, but in some taxa, a subset of these pores is elaborated into lensed eyes, which have been shown to be capable of simple vision. The aesthete pores and "eyes" are connected to the main body beneath the shell by a network of tissue-filled channels, meaning the shell comprises a substantial proportion of volume that is not solid. In more derived species, the channels coalesce in distinct arrangements and their exit points form shell features that are routinely used in taxonomic identification. The internal arrangement of the aesthete canals is challenging to visualise within the solid opaque shell. We used synchrotron radiation X-ray tomographic microscopy, similar to micro-CT scanning, to create three-dimensional models of chiton valves from more than 20 species across the diversity of Polyplacophora and trace these canals within them. Aesthete features are known to vary among major clades, and these represent neurological features with important phylogenetic signal, and our new data could also act as important taxonomic characters. Simultaneously, this dataset allows us to investigate the potential constraints on the arrangements of these sensory structures, as in all cases in Metazoa the penetration of the skeletal elements by nerve tissue should not overly compromise its structural integrity.

P2.258 SILLIMAN, RS*; LOPPNOW, TN; DELONEY-MARINO, CR; CHAMPAGNE, AM; Univerisity of Southern Indiana; *rasilliman@eagles.usi.edu*
Effect of seasonal changes on anitmicrobial defenses in the avian stratum corneum I: Changes in lipid compostition with season
The most superficial layer of skin, the stratum corneum (SC), is composed of several layers of flattened dead cells called corneocytes embedded in a lipid matrix. Several studies correlate lipids in the SC with cutaneous water loss, and have shown that the composition of lipid classes changes in response to changes in ambient humidity. In addition, a potential dual role of lipids in the SC has recently emerged, as many lipids in the skin exhibit antimicrobial activity. In this study, we collected House Sparrows (*Passer domesticus*) in the summer and winter in southern Indiana and extracted lipids from the SC. We then used thin layer chromatography to identify and quantify these lipids. We found that winter birds had fewer lipids in the SC than summer birds, and the composition of lipid classes differed between seasons. These differences in the amount and composition of lipids may have implications for the ability of birds to regulate bacterial community composition on their skin.

P2.56 SILLIMAN, K*; HURT, C; INDORF, J; BROWNE, W; University of Chicago , Tennessee Tech University , University of Miami, University of Miami; *ksilliman@uchicago.edu*
Rate of DNA Mutations Across the Genome of Alpheus Snapping Shrimp
The rate of DNA substitution is an essential parameter as it offers evolutionary biologists the ability to put a timescale on the history of life. Calibration of this rate requires independent information on the timing of species divergence. The final closure of the Isthmus of Panama, approximately 2.7 to 3.5 mya, created a nearly impenetrable barrier to gene flow for thousands of marine taxa. By far the most cited transisthmian-based molecular clock calibrations comes from the snapping shrimp genus *Alpheus*. Most transisthmian molecular clock calibrations have been limited to nucleotide sequence data from mitochondrial genes. The development of reduced representation library techniques, such as Genotype-by-Sequencing (GBS), offers powerful tools for both identifying and genotyping genome-wide loci for use in phylogeographic studies. Basic information regarding the rate and patterns of nucleotide substitutions across loci targeted by approaches like GBS are needed to fully make use of genome-wide polymorphism data in population genetic and phylogeographic studies. We conducted a comparative genomic study on three transisthmian *Alpheus* species pairs to examine rates and patterns of molecular divergence across the nuclear genome. GBS datasets were generated for three species pairs, *A. malleator/ A. wonkimi*, *A. formosus/ A. panamensis*, and *A. colombiensis /A. estuarensis*. Previous work suggested that divergence times for these taxa were contemporaneous and likely to have resulted from the final closure of the Isthmus. Coalescent-based Bayesian methods, including G-PhoCS, were used to examine the rates of DNA substitutions that accumulated across the nuclear genome. To our knowledge this is the first use of transisthmian species pairs to calibrate the rate of molecular evolution across the nuclear genome.

54.4 SILLIMAN, K*; EERNISSE, D; WALTER, R; University of Chicago, California State University Fullerton; *ksil91@gmail.com*
Population Genomics and Phylogeography of the Olympia Oyster
Understanding the evolutionary processes that cause populations to diverge genetically and phenotypically is crucial to predicting how species will respond to rapid global environmental change. The Olympia oyster, *Ostrea lurida*, is patchily distributed from California to the central coast of Canada, extending over strong environmental clines and mosaics that are typically considered necessary for local adaptation to occur. Before testing hypotheses of adaptation, however, the underlying demographic population structure must be described. This pattern could be consistent with a null model of no significant population structure, a continuous isolation-by-distance (IBD) model, or contain regional blocks of genetic similarity separated by barriers to gene flow. We hypothesized that, by using thousands of genetic markers, evidence of regional population structure and IBD will be observed across the species' range. Adult Olympia oysters were sampled across 20 sites from Klaskino Inlet, Vancouver Island (50° 17' 55") to San Diego Bay, CA (32° 361' 9"), as well as 15 individuals from the sister species, O. conchaphila. DNA from these samples were used to construct reduced representation Genotype-by-Sequencing libraries (GBS) and genotype thousands of single nucleotide polymorphisms (SNPs). A Mantel test using Fst and water distance rejected the hypothesis of pure isolation by distance. Using a new method to visualize spatial population structure called EEMS (Estimated Effective Migration Surfaces), we have identified a phylogeographic divide between Puget Sound, WA and Willapa Bay, WA. Although this method cannot distinguish between different scenarios that could produce the observed spatial structure, it supports the rejection of both a continuous IBD model and the null model of no significant genetic structure.

124.6 SIMARD, CS*; PALMER, AR; Univ. of Alberta, Edmonton & Bamfield Marine Sciences Centre; *simard@ualberta.ca*

Too many podia, too little coordination? Sea stars on surface tension

To move effectively in one direction, sea stars must somehow coordinate the motion of hundreds of podia arrayed along arms that point in multiple different directions. Podia coordination has previously been attributed to either central nervous control or to some form of local proprioceptive system. However, considerable debate still exists over how coordination is achieved. To test whether sea stars coordinate their tube feet via central nervous control or via local proprioceptive cues, we tracked the movements of multiple individual podia in juvenile sea stars that attached one or more rays to the surface tension of seawater. Sea stars were filmed walking upside-down on the surface tension and on an adjacent floating glass cover slip to compare podia movements simultaneously on both surfaces. We found that podia do attach to the surface tension and do attempt to propel the sea star, but these attached movements were much less coordinated than when podia attached to a glass surface. We also tracked the recovery strokes of individual podia and their neighbors on these two substrata to test how coordinated recovery motions were. Our results suggest that local proprioceptive cues are important for effective echinoderm locomotion but we cannot entirely rule out the contribution of central nervous coordination.

15.3 SIMS, RJ*; SMITH, KM; CHILDRESS, MJ; Clemson University; *rsims@g.clemson.edu*

Defenders of the reef: Impacts of damselfish territoriality on coral reef community structure

Herbivores play an important role in coral reef communities by preventing the overgrowth of coral by macroalgae. However the interactions of these herbivores may actually facilitate the growth of macroalgae rather than its removal. Previous studies have found that small reef herbivores, such as damselfish, are fierce defenders of their algal gardens and have the potential to limit the grazing of larger herbivores such as parrotfishes. In this study, we examined the abundance and species composition of damselfish across 14 reefs of the Florida Keys National Marine Sanctuary known to vary in coral and macroalgae cover. We utilized a combination of direct observations and remote videos to record the behavioral interactions of damselfishes and parrotfishes. Damselfish abundance was unrelated to algal cover or parrotfish biomass, but increased significantly from inshore to offshore. Algal cover was not significantly different inside versus outside of damselfish territories. Damselfish aggression differed by species, and was positively related to both damselfish and parrotfish densities, but was unrelated to body size, territory size, algal cover or individual boldness. A majority of aggressive acts were directed toward other damselfish rather than larger herbivores like parrotfish. These results suggest the presence and behaviors of damselfish may not strongly influence algal cover or the herbivory of parrotfishes.

P2.149 SIMS, O.C.*; DEAROLF, J.L.; Hendrix College, Conway, AR; *simsoc@hendrix.edu*

Swimming preference of guinea pigs

It is known that guinea pigs (*Cavia porcellus*), among other rodents, are able to swim. However, in previous studies, rodents were forced to swim by being placed into water, and therefore, the investigators may have been determining the effects of stress and exercise on their characteristics of interest, rather than just exercise. Thus, it is currently unknown whether or not rodents would choose to swim in a laboratory setting. The goal of this study is to determine if young female guinea pigs will choose to swim. If they do, swimming can be used as a form of exercise in future studies. Swimming preferences of the guinea pigs were determined using a y-maze consisting of a platform, representing the stem of a traditional y-maze, and the arms of the y-maze consisted of two ramps leading into plastic buckets. The animals were acclimated to the maze in which both arms were dry paths to a reward (timothy hay) over a three-day period (30 min/day). Any animal that moved off the platform of the maze continued on to the choice study. Initially, both arms of the y-maze contained dry paths to a reward, and the position of the guinea pig was recorded every minute for 45 min. Then, the right and left ramps and right and left bundles of hay were switched for a second 45-minute trial. The following day, the same procedures were utilized, but one of the arms of the y-maze contained warm water (between 35 and 40°C) deep enough to require the guinea pig to swim, and when the ramps and hay bundles were switched for the second 45 min trial, so were the buckets of water. The proportions of time spent by the guinea pigs in the left and right arms of the maze during the dry/dry and dry/wet trials will be compared in order to determine if they demonstrate a preference for a wet or dry environment.

23.4 SINKIEWICZ, DM*; WILCZYNSKI, W; Georgia State University; *dsinkiewicz1@gsu.edu*

Impact of sex and region on gene expression in Hyla cinerea brain

Identification of genes and molecules associated with vocalization have been primarily associated with vocal learning leaving a dearth of knowledge regarding the genetics of unlearned vocalizations. *Hyla cinerea* (green treefrogs) offer a unique opportunity to identify differences in communication strategies in an innately vocalizing species. Only male green treefrogs produce a vocalization, which is unlearned, suggesting the genes associated with vocalization are expressed in a sex dependent manner. Unfortunately, there are few genetic sequences available that are specific to *H. cinerea*. To remedy this, we produced a de novo transcriptome of *H. cinerea* brain tissue using stranded RNA-seq and assembled using Trinity. Following assembly, we identified differentially expressed transcripts based on sex, region (forebrain, midbrain, and hindbrain), and for each region between sex using the R package DESeq2. We identified 267 transcripts that are differentially expressed based on sex. When brain region was considered independent of sex we identified 2194 and 588 differentially expressed transcripts between the forebrain and the hindbrain and midbrain, respectively. Additionally, we identified 422 differentially expressed transcripts between the midbrain and the hindbrain. When comparing sex by region we identified 259, 160, and 248 differentially expressed transcripts between forebrain, midbrain, and hindbrain, respectively. Transcripts were considered differentially expressed when the FDR<0.05. These results provide a toolkit with which to investigate genetic differences associated with communication behavior and potentially identify a novel genetic pathway associated specifically with the production of unlearned vocalizations.

P1.287 SKATES, DI*; BALL, N; ELSEY, RM; LAPPIN, AK; OWERKOWICZ, T; CSUSB, RWR, CPP;
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Cranial shape and bite force are not affected by death-roll feeding behaviour in the American alligator

Increased jaw loading during feeding induces a strong hypertrophic response in jaw bones and adductor muscles in mammals, but such plasticity has not been investigated in reptiles. The American alligator (Alligator mississippiensis) is an opportunistic predator, capable of swallowing small items with minimal oral processing, as well as tearing large prey apart in a violent death roll. The latter behaviour exerts large forces on the crocodilian jaw apparatus, which may alter its cranial growth trajectory. We studied whether death-roll training can induce a plastic response in skull shape and bite-force performance in juvenile (400-2500 g) female alligators (n=32 per group). For eight months, experimental animals fed by performing death rolls on chicken drumsticks twice a week, while control animals were fed small chunks of chicken meat. Following training, unilateral bite forces were measured in triplicate, and the jaw out-lever for each trial determined from a video recordings. Body mass and head size had a significant effect on the maximum bite torque, but death roll did not. There was no significant difference of feeding mode on relative cranial shape (head width:length, snout:braincase length). The correlation coefficient of standardised bite force on body mass was greater in experimental animals (0.76) than controls (0.38), suggesting that muscle activation is more finely tuned in animals exposed to unyielding prey items. Overall, the alligator skull does not exhibit bone plasticity in response to long-term exposure to high feeding forces. We propose that bone plasticity is not observed in crocodilians, given their sit-and-wait predatory strategy. Whether apparent lack of musculoskeletal plasticity is ancestral for archosaurs, or derived in crocodilians, is yet to be determined.

P2.275 SKOPEC, MM*; JENSEN, D; SCHRAMM, K; DEARING , MD; Weber State University, University of Utah;
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Biotransformation Enzyme Expression in Nasal Epithelium of Woodrats Consuming Juniper

When herbivores consume plants with volatile plant secondary compounds (PSC), the only barrier between their nasal passageway and their brain is the nasal epithelium. While it is known that the nasal epithelium expresses biotransformation enzymes capable of metabolizing inhaled toxins, the regulation and role of these enzymes is poorly understood, especially in mammalian herbivores. We therefore sought to better understand how the presence of volatile PSCs may alter the expression of biotransformation enzymes in the nasal epithelium of woodrats (genus *Neotoma*). Using Western Blots we compared the expression of four enzymes, cytochrome P450 (CYP) 2B, CYP1A, catechol-O-methyl transferase and glutathione S-transferase in nasal epithelium and livers of woodrats consuming control and juniper diets. Two of the woodrat species were juniper specialists (*N. stephensi* and *N. lepida* from the Great Basin Desert), one species was a dietary generalist that can consume only small amounts of juniper (*N. albigula*) and the fourth species was a creosote specialist with evolutionary history consuming juniper (*N. lepida* from the Mojave Desert). We found that the expression patterns of biotransformation enzymes in the nasal epithelium of woodrats was species specific and that expression of the enzymes in the nasal epithelium was not correlated with the expression of the same enzyme in the liver. Of particular interest, *N. stephensi* showed either lower expression than the other species or downregulation of all four biotransformation enzymes in their nasal epithelium when consuming juniper. We propose that *N. stephensi* may forgo metabolizing the terpenes present in juniper at the nasal epithelium in order to use those terpenes for foraging cues.

122.7 SKRIP, M; SEERAM, N; YUAN, T; MA, H; MCWILLIAMS, S*; University of Rhode Island; *srmcwilliams@uri.edu*

Dietary antioxidants and flight exercise affect how female birds allocate nutrients to eggs: how carry-over effects work

Physiological challenges during one part of the annual cycle can carry over and affect performance at a subsequent phase, and antioxidants could be one mediator of trade-offs between phases. We performed a controlled experiment with zebra finches to examine how songbirds use nutrition to manage trade-offs in antioxidant allocation between endurance flight and subsequent reproduction. Our four treatment groups included a factorial combination of exercise/sedentary groups and diet supplemented/non-supplemented groups with the supplement including water- and lipid-soluble antioxidants. After flight training, birds were paired within treatment groups for breeding. We analyzed eggs for lutein and vitamin E concentrations and the plasma of parents throughout the experiment for non-enzymatic antioxidant capacity and oxidative damage. Exercised birds had higher oxidative damage levels than non-exercised birds after flight training, despite supplementation with dietary antioxidants. Supplementation with water-soluble antioxidants decreased the deposition of lipid-soluble antioxidants into eggs and decreased yolk size. Flight exercise also lowered deposition of lutein, but not vitamin E, to eggs. These findings have important implications for future studies of wild birds during migration and other oxidative challenges. Supported by NSF (IOS-0748349 & IOS-135417 to S.R.M.), USDA (RIAES-538748 to S.R.M.), and AOU and Sigma Xi student research awards to M.M.S.

139.5 SLATER, GARETT*; HELM, BRYAN; YOCUM, GEORGE; BOWSHER, JULIA; SLATER, garett; North Dakota State University, Fargo, ND, USDA-ARS, Fargo, ND;
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The fallacy of honeybee caste determination: how quantity, not quality, may determine caste

A Honeybee colony comprises thousands of sterile workers and one reproductive queen. While workers and queens are genetically analogous, they are morphometrically and physiologically disparate. Although all the individuals develop into workers unless queen development is necessary, each fertilized larvae has queen latency. This queen-worker divergence occurs when 3rd instar larvae receive a high quality diet of royal jelly. However, our recent work indicates diet quantity has a strong influence on caste in honeybees. A large amount of lower-quality diet can induce queen formation, but it is unknown whether queen induction under these conditions uses the same hormonal and cellular mechanism as queen induction at the third instar. The aim of this study is to determine the hormonal control and cellular mechanisms inducing queen formation under a range of diet quantities and qualities. In vitro rearing was used to control for both diet quantity and quality. We measured juvenile hormone titers and quantified transcript levels for Target of Rapmyacin (TOR), and Insulin Like-Peptides(IIS). Caste was confirmed using a principal component analysis (PCA) on multiple morphological indicators of caste. This research has implications for understanding both caste determination and queen quality.to confirm dietary quantity control of caste

4.4 SLEBODA, DA*; ROBERTS, TJ; Brown University;
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Are all skeletal muscles helically-reinforced hydrostats?

Extracellular connective tissues surround muscle fibers, fascicles, and whole muscles. They are arranged in complex, roughly helical patterns, and this arrangement allows them to play important roles transferring force between muscle fibers and facilitating whole muscle shape changes. The prevalence and organization of connective tissue varies considerably in different muscles, both within and across species, but the functional consequences of these structural variations are not well understood. A means of simplifying and modeling connective tissue morphology is needed, and we suggest that an appropriate theoretical framework for this already exists within the field of biomechanics. Helically-reinforced hydrostats represent a class of structures occurring in a huge variety of species; in the bodies of worms and sharks, in the tube feet of starfish, and in the roots of trees, among many other examples. Helical hydrostats have been thoroughly modeled, and share a number of structural characteristics with skeletal muscle. Both incorporate helically-arranged connective tissue fibers which surround and reinforce constant-volume fluid-filled structures, and both utilize alterations of collagen fiber geometry to accommodate changes in length and shape. Can mathematical models and theory developed for the study of helically-reinforced hydrostats be applied to the study of intramuscular connective tissue? We provide empirical support for geometric models of connective tissue which incorporate hydrostat-like elements, and explore the potential for these models to increase our understanding of passive tension and other fundamental mechanical properties of muscle.

80.1 SMALL, TW*; BRIDGE, ES; ELDERBROCK, EK; SCHOECH, SJ; University of Memphis, University of Oklahoma;
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Food supplementation only improves reproductive success in higher stress-responsive Florida Scrub-Jays (Aphelocoma coerulescens)

In a wide variety of vertebrates, plasma glucocorticoid (CORT) levels rapidly increase in response to a stressor but the magnitude of the stress-induced CORT (SI-CORT) response can consistently vary among individuals. In Florida Scrub-Jays (*Aphelocoma coerulescens*) these individual differences in SI-CORT are repeatable throughout the adult lifespan (up to nine years) and are predictive of sex-specific differences in lifespan (lower SI-CORT males and higher SI-CORT females live longer). The specific causes for the differences in life-span associated with SI-CORT are not clear but, in general, the longer lived SI-CORT phenotypes have lower annual reproductive success. We investigated how SI-CORT phenotype influenced individual reproductive strategies and reproductive success using a novel "SmartFeeder" design that utilizes radio-frequency identification (RFID) technology to selectively provide live mealworms to specific individuals within a free-living population of Florida Scrub-Jays. Overall, supplemented jays raised more offspring to nutritional independence (~70 days old), however, this effect was only observed in males and females with moderate to high SI-CORT responses. Further, the effect of supplementation was strongest in pairs with two high SI-CORT individuals, but high SI-CORT jays paired with low SI-CORT jays showed no improvement over controls. Together, these data suggest that SI-CORT phenotype influences reproductive strategies in both male and female Florida scrub jays and annual reproductive success is heavily influenced by the interaction of SI-CORT phenotypes within a breeding pair.

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Phenotypic Plasticity in Oysters Mediated by Chemical Cues from Predators and Injured Prey

To balance energy expenditures on predator avoidance and deterrence with critical life history functions such as energy acquisition, growth, and fecundity, many prey organisms use plastic responses to predation risk that are employed when risk of injury or death is imminent. Oysters are preyed upon by numerous species and react to predatory threats by altering their shell morphology at a cost of producing less gonad tissue. We tested oyster responses to predation risk in the field and measured chemical changes in shells when blue crab predators were present. As previously reported from laboratory investigations, oyster spat grew broader, flatter, heavier, and significantly stronger shells in treatments with blue crabs. Oysters in crab treatments had significantly greater amounts of inorganic material in their shells. In contrast, control oysters had significantly greater organic matter in their shells, suggesting that they alter their shell growth by switching from organic to inorganic shell production to increase shell strength. We tested oyster morphological responses to various risk cues including injured con and heterospecifics as well as blue crabs reared on different diets. Oysters grew heavier, stronger shells in response to cues from injured prey and well as blue crabs, with the strongest shells occurring in treatments with blue crabs fed live oysters. Oyster shells were stronger than controls but weaker than in the treatment with blue crabs fed live oyster after exposure to injured prey cues as well as to crabs consuming a diet of dead tissue. Thus, oysters can differentiate between different types of risk cues, including those released by predators vs. scavengers and also react to alarm cues from sympatric prey.

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The Effects of Bromocriptine and Reproductive Experience on Prolactin and Parental Behavior in the Zebra Finch

Parental care is a widespread phenomenon observed in many diverse taxa. Neuroendocrine systems have long been thought to play an important role in stimulating the onset of parental care behavior. In most birds with altricial young, circulating prolactin (PRL) levels are low during non-breeding times and significantly increase during late incubation and early post-hatch chick care. Because of this pattern, PRL has been suggested to be involved in the initiation of parental care in birds, but rarely has this hypothesis been causally tested. In order to begin testing the hypothesis, we inhibited the release of endogenous PRL on the three days prior to hatching in incubating parents and the first two days of post-hatch parental care, when PRL was found to be highest during the breeding cycle in zebra finches. Zebra finches are socially monogamous and biparental, which allows both males and females to be tested. Breeding pairs were randomly assigned to receive either 5 daily treatments of bromocriptine (BR; n=20), a proven inhibitor of PRL release, or vehicle control (n=20). BR was suspended in peanut oil and all treatments were administered orally via a pipette. During treatment, nest temperatures were recorded. On the last two days of treatment, parental behavior was recorded inside the nest with chicks. In addition to hormonal systems, reproductive experience may also influence parental care. Therefore, we tested age-matched inexperienced and experienced pairs in each both treatments, yielding a 2x3 design (sex X treatment X experience). We predict that there will be no sex differences and that BR-treated birds will show less parental care and have lower nest temperatures than controls. In addition, we predict inexperienced birds will show less behavior and have lower nest temperatures than experienced birds. Results will be presented and discussed.

P1.147 SMITH, P. N.*; BALTZLEY, M. J.; BOOMER, S. M.; Western Oregon University, Monmouth; *pnsmith13@mail.wou.edu*
The Gut Microbiota of Helix aspersa
The gut microbiota plays an important role in the host organism's well-being, contributing to the host's immunity and metabolism. An individual's total gut microbiota is dynamic, fluctuating in response to changes in diet and environmental stressors; however, a host often has a subset of gut microorganisms, known as the core gut microbiome, which is consistent among individuals in a population. To study the gut microbiota, we are using the common garden snail, *Helix aspersa*, as our model organism. In the past, culture-based studies have been used to identify bacteria from the gut of *Helix aspersa* raised on processed food sources, which can alter the gut microbiota. Little has been done using metagenomics to determine the natural gut microbiota or identify a core microbiome. We analyzed 16S bacterial diversity in the feces of wild-caught snails using high-throughput Illumina sequencing of the V1 and V2 variable regions. Our results show a gut microbiota dominated by Gammaproteobacteria, particularly members of genus *Buttiauxella*. This finding was notable in that several early culture-based studies identified this genus as snail specific. More recent DNA-based work has identified this genus at low levels in soil and water environments. Given these data, we assessed the microbial community present on the snail food source (whole-leaf lettuce), confirming low levels of *Buttiauxella* and high levels of *Pseudomonas*. This finding suggests that *Helix* selectively uptake microbes from their food-source and/or avoid potentially harmful *Pseudomonas*. We are using FISH microscopy and plating techniques to study changes in the gut microbiota of individual snails in response to changes in their feeding regimen, and exposure to antibiotics or bacterial stressors.

86.7 SMITH, AM*; FUNG, TM; PAPALEO, C; REID, C; BLISS, JM; WOLF, I; HARRO, C; Ithaca College, Bryant University, Brown University; *asmith@ithaca.edu*
Transcriptome-based sequencing and mechanical measurements elucidate the energy dissipation mechanism of an unusually tough biological glue.
The terrestrial slug *Arion subfuscus* produces a defensive secretion from its dorsal surface that rapidly sets into a tough, adhesive hydrogel. The gel can sustain stresses of over 100 kPa, and can extend to more than ten times its initial length. Thus, it requires far more energy to fracture than a typical hydrogel. The glue gains this toughness through a double network mechanism. In the proposed model, a network of cross-linked proteins makes the glue stiff, and an interpenetrating network of large polysaccharides causes it to deform extensively before failure. This model suggests that there will be a large number of "sacrificial bonds" within the protein network that provide stiffness, but rupture and thus dissipate energy as the glue deforms. Cyclic stress-strain measurements of the glue demonstrate that the glue behaves like an elastic, cross-linked network, but as it extends, bonds are continuously ruptured, leading to a dramatic reduction of modulus in subsequent trials. The primary structure of all the proteins in the glue was determined using high-throughput Illumina sequencing of the transcriptome followed by tandem mass spectrometry to identify specific proteins. Most of the proteins that form the cross-linked network consist of conserved calcium binding domains that typically mediate intermolecular cross-links. Biochemical evidence confirms that the proteins have a high capacity to bind to calcium. These data are consistent with a calcium-cross-linked protein network providing stiffness and energy dissipation.

S9.7 SMITH, Jennifer E.*; PETELLE, Matthew B. ; JEROME, Emily L. ; CRISTOFARI, Hélène ; BLUMSTEIN, Daniel T. ; Biology Department, Mills College, Oakland, CA, Department of Ecology & Evolutionary Biology, University of California, Los Angeles, CA; *jesmith@mills.edu*
The role of oxytocin in shaping prosocial behavior: new evidence from free-living ground squirrels and other social mammals
Whereas oxytocin has gained a reputation as the "love drug" or "cuddle hormone", emerging evidence indicates the need for a more comprehensive view in understanding its role in regulating prosocial behaviors. Here, we revisit the salience of oxytocin in the lives of free-living social mammals. First, we investigated the potential for oxytocin to promote social cohesion in yellow-bellied marmots (*Marmota flaviventris*). We intranasally-administered oxytocin or a saline control to 18 subjects in field experiments. Behavioral responses in the mirror-image stimulation (social) tests were highly variable among subjects and were not significantly different between treatment and control groups. Second, we reviewed the literature to understand the potential for strong positive effects of oxytocin in promoting prosocial behaviors in non-humans. Our review highlights some common pitfalls associated with oxytocin studies, a strong bias for studies of model organisms in highly-controlled settings, and emerging evidence for oxytocin's antisocial, context and sex-specific effects. Taken together, these findings lead us to join others in calling for revision of an overly simplistic view of oxytocin's role in promoting mammalian behavior. In doing so, we provide a more nuanced roadmap for moving the field forward by emphasizing the complexities of these effects in shaping prosocial tendencies in the social lives of animals in naturalistic settings.

P3.79 SMITH, RA*; DUPONT, KR; UHL, L; SKOPEC, MM; Weber State University; *rasdude08@gmail.com*
Building and Caching Behaviors of Woodrats in a Laboratory Setting
Woodrats (genus *Neotoma*) are well known for their building and caching behaviors and build elaborate structures called middens. In the wild, middens serve as shelter and a storage site for their caches. While the caching behavior of woodrats has been rigorously studied in captivity, building behavior studies are lacking. We wanted to determine if building and caching behavior could be empirically studied in a laboratory setting. Three groups of woodrats were used in the experiment: *N. albigula*, *N. lepida* from the Mojave desert, and *N.lepida* from the Great Basin desert. These species of woodrats are commonly found in desert terrain where resources are limited and all three display different midden structures in the wild. To test for differences in building and caching behavior the woodrats were placed in a nesting cage that had access to a secondary area that contained objects the woodrat could use for building or caching. The caching objects included jingle bells and rabbit chow (food) while the building objects included sticks and cotton nesting material. Each day the objects used or collected were counted and replenished. There were significant differences in building and caching behaviors between species. *N. albigula* favored cotton equally to sticks and bells, but favored sticks more than bells. Great Basin *N. lepida* favored cotton more than sticks and bells, which were favored the same. Mojave *N. lepida* preferred cotton more than sticks and sticks more than bells. We conclude that woodrats do display species specific building behavior in the laboratory. Additional information collected via remote video surveillance will reveal the amount of time devoted to building and caching activity.

15.4 SMITH, KM*; CHILDRESS, MJ; Clemson University ; *kylie4@clemson.edu*

Top-down versus Bottom-up Regulation of Coral Cover in the Florida Keys

Caribbean coral reefs have drastically changed over the past 30 years with declines in coral cover and herbivore abundance. In order to regulate increasing competitive macroalgae, protecting the remaining reef herbivores has become a primary conservation goal throughout the Caribbean. However, this assumes that corals are limited primarily by the top-down indirect effect of herbivores on macroalgae. To test the predictions of this herbivore cascade hypothesis along with alternative bottom-up hypotheses, we surveyed the reef community structure (parrotfish abundance and substrate cover) of 34 reefs in the middle region of the Florida Keys National Marine Sanctuary. Reef physical structure was estimated by the first principle component composite variable (distance from shore, depth, visibility, substrate complexity). We estimated the major influences on percent coral cover using both multiple regression analysis and structural equation modelling. Both methods suggest that there are positive top-down (parrotfish), negative bottom-up (reef structure) and negative competitive (fleshy algae) influences on coral. However, the structural equation models suggest that these are not driven by strong negative interactions of parrotfish on turf or fleshy algae. Analysis of parrotfish foraging behavior suggests that diet composition is highly variable and preferences for algae change with relative abundance. These results suggest that hard corals of the middle Florida Keys may be regulated by a complex interaction of top-down and bottom-up influences independent of parrotfish herbivory.

61.3 SMITH, GD*; DURSO, AM; ANGILLETTA, MJ; DENARDO, DF; FRENCH, SS; Utah State University, Arizona State University, Arizona State University; *geoff.smith@usu.edu*

Assessing the protein and metabolic costs of a trade-off between reproduction and immunity

Trade-offs between competing physiological systems comprise a core pillar of life-history theory, but the mechanisms that govern these processes are still poorly understood. Moreover, quantifying the amount and type of resources invested to critical physiological systems is inherently complicated and context-dependent. In a 2x2 design, we injected female side-blotched lizards with follicle-stimulating hormone to increase their reproductive investment and subjected them to an immune challenge (cutaneous biopsy), while measuring their oxygen consumption at different time points to assess the metabolic demands of these competing challenges. In addition to this, we injected the lizards with a stable nitrogen isotope and dissected them at the end of the experiment to measure what tissues had the highest demand for protein. Lizards that invested larger quantities of protein into their eggs had larger increases in metabolic rate, but lizards that had faster wound healing had larger decreases in metabolic rate, and the relationship of this change was related to the rate of healing. Additionally, lizards with increased reproductive investment exhibited higher levels of reactive oxygen metabolites. Although neither treatment affected either performance outcome directly, both simultaneously altered metabolism and protein investment, and thus differentially altered overall resource allocation strategy, indicating that both these processes are critical for an animal's persistence.

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Local adaptation of the hypothalamic-pituitary-adrenal axis in lizards in response to a predator

Predators are known to affect population size and demography of their prey by increasing mortality. However, the nonlethal effects of predators are sometimes overlooked. Predators can alter foraging behavior and habitat selection in prey animals, as well as reproductive physiology and phenology. In this study, we sampled side-blotched lizards in eastern Oregon from a single metapopulation occupying adjacent canyons along the Owyhee River, but separated by a perennial stream. The primary difference between sample sites was the presence or absence of collared lizards, a large, predatory lizard that preys upon side-blotched lizards. Side-blotched lizards occurring with collared lizards had lower body condition and delayed vitellogenesis, likely due to more cautious foraging or reduced foraging opportunities. Additionally, side-blotched lizards occurring without collared lizards had higher baseline corticosterone concentrations and a stronger response to a uniform stressor. Although stress response is adaptive for escaping predators, chronic stress can cause deleterious effects to cognitive, immune, and reproductive systems, reducing overall fitness. Thus we infer that constant pressure from a large and conspicuous predator may have caused side-blotched lizards to adopt a blunted stress response.

S7.10 SMITH, FW*; GOLDSTEIN, B; University of North Carolina at Chapel Hill; *frank.w.smithiii@gmail.com*

Development and Evolution of the Tardigrade Body Plan

We aim to elucidate the developmental principles that govern the evolution of animal body plans. The phylum Tardigrada is part of the superphylum Panarthropoda, which also includes the phyla Euarthropoda and Onychophora. Understanding the origin of the tardigrade body plan is critical for illuminating the evolution of panarthropod body plans more generally. Here we present results of our recent studies of anteroposterior patterning genes, which reveal two important aspects of tardigrade body plan evolution. First, our results suggest that tardigrades have lost a relatively large portion of the anteroposterior body axis. This result supports a model in which the ancestor of Panarthropoda was a relatively elongate animal, rather than a compact animal like a tardigrade. Second, our recent results suggest that tardigrades possess a unipartite brain, rather than a tripartite brain like euarthropods. This conclusion supports a model in which a tripartite brain organization is a synapomorphy of Euarthropoda, while the ancestor of tardigrades and euarthropods possessed a unipartite brain. We present additional ways in which developmental studies of tardigrades could illuminate the evolution of panarthropod body plans.

P3.247 SMITH, TD*; MCMAHON, MJ; MILLEN, ME; LI, L; LLERA, C; BURROWS, AM; ZUMPANO, MP; DELEON, VB; Slippery Rock Univ., Duquesne Univ., Univ. or Florida, New York Chiropractic College; *tdsmith@gmail.com*
Growth characteristics of the anterior cranial base and midface in newborn primates
The sphenoethmoidal synchondrosis, or prespheno-septal synchondrosis (PSept), is reported to remain unfused until six to seven years in humans. In non-human primates, it is reported to be fused perinatally. However, only macaques have been studied to date using histology. Here, we examined the hypothesis that humans are unique in prolonged PSept patency using ontogenetic samples of monkeys, strepsirrhine primates (lemurs and lorises), and a comparative sample of other mammals. Specimens ranging from late fetal to one month postnatal age were studied using histology, immunohistochemistry, and micro-computed tomography methods. We found that none of these nonhuman primates lack a PSept at birth, although monkeys have a distinct joint shape. Unlike strepsirrhines and other mammals, monkeys have a convex anterior end of the presphenoid with a radial boundary of endochondral growth. These results show that extended growth at PSept does not distinguish humans from other primates. If synchondroses are significant to the uniquely flexed cranial base angle of humans, other joints would be more relevant (e.g., intrasphenoidal synchondrosis). In a broad sense, the synchondroseal growth patterns reveal a basic dichotomy between strepsirrhines (resembling other mammals) and anthropoids that is more directly applicable to facial form. Our findings imply that the septal cartilage may set the pace of forward midfacial growth at critical time periods, but can also accommodate variations in face shape from the typical mammalian pattern that directs growth of relatively longer snouts.

P2.246 SMITH, B*; HAPGOOD, J; GILLIUM, T; CROSSLEY, D; University of North Texas; *brandtsmith@my.unt.edu*
Developmental phenotypic plasticity of ventilatory patterns and metabolic function of the American alligators (Alligator mississippiensis)
Developmental hypoxia has been established as a powerful stimulus that induces phenotypic change in organism. Further, in species the routinely experience this developmental challenge, hypoxic exposure may alter the maturation of traits resulting in an advantageous phenotype in the juvenile and adult. American alligator embryos have been documented to experience bouts of hypoxia during the incubation period, indicating this is a relevant challenge for the species. Prior studies have demonstrated the developmental hypoxia alters the phenotype of embryonic alligators however the lasting impact post hatching is largely unknown. In this study we investigated the impact of developmental hypoxic on ventilation and metabolic function of America alligators 2 yrs post hatching. In this study we investigated the impact of developmental hypoxic on ventilation and metabolic function of juvenile America alligators (*Alligator mississippiensis*). Measurements consisted of ventilation frequency, apneic periods, oxygen consumption and carbon dioxide production in animals that were incubation in 21% or 10% oxygen. Our preliminary assessment suggests hypoxic incubated juvenile alligators exhibit greater ventilator frequency with shorter periods of apnea. These findings suggest ventilation patterns are established during the embryonic period and exhibit developmental phenotypic plasticity.

90.5 SMITH, B*; WEST, T; USHERWOOD, J; Royal Veterinary College; *bsmith@rvc.ac.uk*
Effects of chronic hypergravity exposure on mouse locomotor muscle and kinematics
Our previous studies into the effects of short term exposure to centrifuge induced hypergravity on the kinematics and kinetics of running mice have shown that mice transiently adapt their postures and gaits in response to higher effective gravity; this is consistent with the minimization of muscle activation costs due to peak power demands. It is well known that long term exposure to both increased and reduced gravity has significant effects on animals' musculoskeletal systems; could longer exposure to hypergravity therefore cause adaptations in mouse muscle that would optimize its capacity to produce power, and hence further reduce muscle activation costs? To investigate this we exposed 12 mice to hypergravity equivalent to 1.5 times Earth gravity (1.5g) for 22 hours a day for up to 12 weeks. An equal number of age, sex and strain matched control mice were housed in identical conditions, and with the same array of instruments, at Earth gravity. During this exposure period, kinematic and kinetic measurements were made using an instrumented exercise wheel which measured speed and vertical peak ground reaction force, and an automatically triggered infra-red high speed camera which recorded at 200Hz. At three week intervals three hypergravity mice and three control mice were culled, and their hind limbs dissected. This allowed hind limb muscle properties to be analyzed in conjunction with the kinematic and kinetic data. Not only is this data of interest in the context of fundamental biomechanics, it could also inform our understanding of how long term changes in body weight, such as obesity, affect bone and muscle.

P3.230 SMITH, B*; USHERWOOD, J; Royal Veterinary College; *bsmith@rvc.ac.uk*
Automated measurement of mouse kinematics and kinetics under centrifuge induced hypergravity
Gravity manipulation is a powerful tool for investigating the fundamental mechanics of legged locomotion; observations of how animals adapt their gait and posture to increased load allow work and power optimization to be studied, while changes in gravitational acceleration enable the predictions of pendulum or ballistic based models of locomotion to be tested. Centrifuge induced hypergravity has a number of advantages over other techniques such as mass loading or attaching springs to the body; it has the same effect on both the body and limbs, animals are able to move around freely, and exposure can be maintained for long periods, allowing long term physiological adaptations to be studied as well as shorter term changes in gait or posture. Previous studies of the effects of centrifuge induced hypergravity on animal locomotion have been limited to estimates of overall activity or measurements of gait and posture after the animal has been removed from the centrifuge. The system presented here allows us to make high resolution observations of kinematic and kinetic parameters while the animals are inside the centrifuge; an instrumented exercise wheel measures speed and vertical ground reaction force, and an automatically triggered camera records high speed video at 200Hz. The centrifuge itself comprises two sets of arms of different lengths, allowing two levels of hypergravity to be achieved simultaneously; the maximum effective gravity at the end of the outer arms is 10 times Earth gravity (10g). We have used this system to investigate acute effects of different effective gravity levels on the kinematics and kinetics of mouse locomotion, and we are in the process of investigating the effect of chronic exposure to hypergravity over a period of months on both locomotion and bone and muscle growth in mice.

60.5 SMITH, N*; GHOSH, R; DICKERSON, AK; University of Central Florida; *dickerson@ucf.edu*
Citus Jets

The internal rupture of oil glands in the flavedo layer of the citrus exocarp results in catastrophic cellular decay to adjacent cells. However, when peeled, the oil gland cavities can rupture outwardly in response to externally applied bending stresses. Bending of the peel compresses the soft material surrounding the glands, increasing fluid pressure. Ultimately, the fluid pressure exceeds the failure strength of the outmost membrane. The ensuing high-velocity discharge of oil and exhaustive emptying of oil glands creates a novel method to atomize small quantities the aromatic and volatile oils. We employ high-speed videography of gland rupture and bending mechanics simulations of navel and Valencia oranges to rationalize the internal pressures and materials properties contributing to fluid ejection. Particle tracking of oil jetting and rheological measurements of oils reveal jet instability and breakup characteristics critical to droplet formation. Particular attention is given to the evolutionary function and potential applications for this novel method of fluid dispersal.

P2.126 SMITH, D*; MADY, R; OUFIERO, C; Towson Univ.; *dms199388@gmail.com*
Are the Athletic Ones the Handsome Ones? Part II: Linking Female Preference to Anaerobic Locomotor Performance in Xiphophorus montezumae

In many species, male members use courtship displays as well as physical traits to attract mates. Females may asses the displays, the ornamentation, or both to determine the quality of her suitors and make a selection. In fish species, females may assess the courtship displays of males based on certain characteristics of their swimming behavior, such as sprint speed, which is the top speed a fish can swim. Male fish may use fast bursts in their courtship displays as a method of out-competing other males. Having a fast sprint speed can also allow a fish to escape predators. Females may analyze sprint speed as a way of gaining the indirect benefit of having offspring that may be fast sprinters, and therefore better able to escape predators. Or, the male's ornamentation may be an accurate indicator of his sprint speed, allowing the female to chose based on his morphology. The goal of this study was to determine if female preference was influenced by a male's sprint speed, morphology, or both using *Xiphophorus montezumae*. Males of this species have an extension of their caudal fin, referred to as a "sword." This has made them ideal for studies on female preference, as well as locomotor performance. Yet a study linking female preference and performance in *X. montezumae* hasn't been done. Sprint speed was quantified by chasing male individuals down a chamber and recording the intervals at which lasers were broken. Female preference was examined using a dichotomous preference test. The morphology of the males was recorded by taking measurements of their physical features, including their sword. Results will be discussed in the context of the relationship among individual sprint speed, morphology and female preference.

108.5 SMITH, AE; WILLIS, MA*; Case Western Reserve University, Cleveland, OH; *maw27@case.edu*
Flight Stability and Olfactory Navigation is Supported by Multisensory Antennal Inputs in the Moth Manduca sexta.

Male hawkmoths, *Manduca sexta*, locate females for mating by tracking wind-borne plumes of female pheromone in flight. The quantity and quality of the odor and the timing of odor encounters are extracted from their environment using input from sensory cells on their antennae. Steering and navigation control are thought to depend on: 1) instantaneous spatial comparison between the two antennae, spatial sampling, or 2) comparison of odor inputs between two sequential sampling points, temporal sampling. If spatial sampling is important for plume tracking, removal of one antenna should diminish their ability to locate an odor source. However, removing one antenna should have less of an impact on temporal trackers, as they could still compare odor cues over time. To characterize the effects of different environments on plume tracking, we challenged males with only one odor-detecting antenna to track a plume in an either turbulent or laminar air flow. More than 50% of moths with only one odor-detecting antenna located the source in turbulent flow, dropping to ca. 30% in smooth air flow. Plumes are wider in turbulent flow and narrower in smooth flow. Males in treatment groups that had difficulty successfully locating the source also showed difficulty hovering. When a donor antenna was attached to the stump of the removed antenna prior to flight "re-loading" the large mechanoreceptors at the base flight stability, hovering and source location was partially recovered, more so in the turbulent flow environment. Bilateral mechanosensory input was more important for successful source location than bilateral odor information. We thank Jen Milligan, Kim Thompson and Sean Copley for their assistance. AES and MAW were supported by NSF grant IOS-1121498 and AFOSR grant FA9550-14-03987.

138.5 SMITH III, JPS*; GOBERT, S; ARTOIS, T; BRAND, J; SCHARER, L; WINTHROP UNIV, HASSELT UNIV, UNIV OF BASEL; *smithj@winthrop.edu*
Evolution of the Proboscis-Armature in Schizorhynchia (Platyhelminthes; Kalyptorhynchia): Multiple origins and losses?

Schizorhynchia includes approximately 150 species of predators that use an anterior proboscis to capture prey. The proboscis comprises dorsoventrally paired muscular tongues often armed with hooks or teeth. Taxonomy in this group has relied heavily on the light-microscopic structure of the proboscis, with the taxa possessing an unarmed proboscis regarded as primitive, and taxa possessing an armed proboscis, as derived. Molecular phylogenies do not support this view—the Cheliplanidae, with a proboscis armed with hooks, is basal, and the genus *Carcharodorhynchus*, with a proboscis armed with teeth, lies immediately above it. Other Schizorhynchia possessing armed proboscides are scattered throughout the tree, suggesting that the proboscis has lost and/or re-evolved armature several times. We examined proboscides in Schizorhynchia using CLSM, TEM, and/or serial-block-face SEM. Comparison of armed proboscides in *Baltoplana*, *Cheliplana*, *Carcharodorhynchus* and *Lehardyia* with the unarmed proboscides in *Proschizorhynchella*, *Carolinorhynchus* and *Schizochilus* suggest that the proboscis has undergone increasing specialization in the basal Cheliplanidae, typified by the rather derived (and speciose) genus *Cheliplana*. In contrast, the armed proboscis in *Lehardyia* bears similarities to the unarmed proboscides, implying that the armature here has arisen from the unarmed condition. Unfortunately, although we have data on prey-preferences of Schizorhynchia from PCR-based diet studies, we lack observations of feeding dynamics necessary to form hypotheses about how prey specialization might have driven morphological evolution in these interesting organisms. Support: WU Research Council and SC-INBRE (P20GM103499 from the NIGMS, NIH)

P1.232 SMOLINSKY, AN*; MIDDLETON, KM; Univ. of Missouri, Columbia; *ansmolinsky@gmail.com*

The effects of muscle- and impact-dominated loading on femoral cross-section morphology and mineral apposition in young outbred mice

Bone plasticity can result in changes in cortical thickness or distribution in the limb skeleton following exposure to different loading environments. However, the relative contributions of muscular contraction and ground reaction force (GRF) to an observed phenotype are not fully understood. We examined the influence of loading environment on femur cross-sectional geometry and mineral apposition in male outbred mice. Four-week-old mice were divided into 4 treatment groups, each exposed to a different source of bone strain for 21 days: downward jumping to increase GRF, swimming to increase muscle loading, wheel running to mimic the combination of muscle and GRF in normal locomotion, and sedentary controls. Mice were injected with fluorochrome bone labels during the last week of treatment. Undecalcified femoral mid-diaphyseal sections were photographed using light and fluorescent microscopy. Images were analyzed for cortical growth patterns and cross-sectional properties (cross-sectional area, moments of inertia). The impact group had significantly greater cross-sectional area, moments of inertia, and polar moments of inertia than controls, indicating increased strength in torsion and bending. Fluorochrome labeling indicated the greatest mineral apposition was posterolaterally in all groups, with additional cortical drift medially or posteriorly characterizing each loading regime. These results demonstrate that impact loading is more effective at increasing bone cross-sectional properties than swimming or running. Future analyses of whole bone morphometrics will further elucidate the roles of GRF and muscle-induced forces in long bone modeling in the context of voluntary locomotion.

P3.27 SMYTH, KN*; STONEHILL, A; CARUSO, N; DREA, CM; Duke University, Durham, NC and The Kalahari Research Trust, Kuruman River Reserve, South Africa , Duke University, Durham, NC, University of Alabama, Tuscaloosa; *kendra.smyth@duke.edu*

Consequences of Prenatal Androgen Exposure for Offspring Health: an Experimental Study in Wild Meerkats

Androgens underlie a well-known tradeoff between reproductive benefits versus health costs in males. Despite substantial variation in female androgen production and the potential for transgenerational effects, this tradeoff is underappreciated in females and their offspring. In the cooperatively breeding meerkat (*Suricata suricatta*), dominant females benefit from raised androgens through increased competitive abilities, particularly during pregnancy, but suffer from androgen-mediated immunosuppression (Smyth and Drea 2016; Smyth et al. 2016). Here, we ask if exposure to raised prenatal androgens produces a comparable trade-off in meerkat pups. From 2012-15, we measured innate immune responses in pups derived from dominant and subordinate control dams, and from dominant dams treated with an androgen-receptor blocker. We found stronger immune responses in pups from dominant versus subordinate dams; however, blocking prenatal androgens improved the pups' innate immune responses. Thus, an ‘inherited,' androgen-mediated immunohandicap may be offset by the social benefits accrued to pups of dominant females.

S8.5 SNELL-ROOD, EC*; SWANSON, EM; University of Minnesota; *emilies@umn.edu*

The effect of nutrition on life-history trade-offs across species

Nutrient availability affects both life-history traits and trade-offs: individuals reared on high quality diets tend to allocate more to a range of fitness-related traits, and trade-offs between such traits are often obscured. While the importance of nutrition for life-history evolution has been extensively studied within species, the relationship is less clear across species. Because species often adapt to low quality diets over time, nutrition may be less important in shaping life histories across species. Here we test the hypothesis that variation in nutrient availability shapes the evolution of life history traits and the expression of trade-offs. Do species on lower nutrient diets allocate less to a range of traits, or must they invest more heavily in individual traits, strengthening underlying trade-offs? Butterflies are a useful system for addressing these ideas because species vary widely in larval diets, which in turn vary in macro- and micronutrient content. We focus on the nitrogen content of a species' diet as nitrogen is the most important macronutrient for insect herbivores. We found the nitrogen content of a species' larval diet is correlated with fecundity (both egg number and relative egg size) and eye size. We then test whether the strength of trade-offs between reproductive traits (egg number, egg size, testes size) and other fitness-related traits (eye size, brain size, thorax mass) vary with diet. We discuss how an integrative view of allocation to a range of traits, and throughout an organism's entire life, is important to understanding life-history evolution.

P2.61 SNYDER, N*; DICKERMAN, L; SCHWALBE, M; LABUHN, M; SINGH, A; REED, W; KITTILSON, J; North Dakota State University; *nicole.snyder@ndsu.edu*

Melatonin and Receptor Signaling: Investigating Roles in Chicken Embryo Development

Maternal investments in eggs affect offspring growth & development, but mechanisms of these effects are not always clear. Melatonin is a hormone with wide ranging effects on phenotypes, & is found in egg yolks. In order to understand melatonin's role in development, we conducted two experiments using chicken embryos (*Gallus gallus*): 1)We dosed eggs with melatonin to understand effects of variation in yolk-derived melatonin on development; 2)We administered agonists & antagonists of the melatonin receptors (Mel1a, Mel1b, & Mel1c) to evaluate their role in early development. We assigned approximately 300 eggs to one of eight treatments: one of four concentrations of melatonin (600,000 pg, 100,000 pg, 1,000 pg, or 100 pg per gram of yolk), Luzindole (Mel1a/1b antagonist), Prazosine Hydrochloride (Mel1c antagonist), 5-MCA-NAT (Mel1c agonist)/Luzindole mix, or saline vehicle. Eggs were injected with 100 ul of their respective treatment before incubation. After approximately two days of incubation we opened eggs, measured embryonic heart rate, staged embryos, & recorded images of embryos for morphological measurements. Melatonin concentration influenced progression of development, but did not follow simple linear response. Heart rate was unaffected by melatonin concentration. Conversely, receptor treatments did not have effect on stage, but blocking of any melatonin receptors decreased overall heart rate. Furthermore, adding a Mel1c agonist restored heart rate to almost normal (vehicle control). We hypothesize embryos possess a minimum & maximum concentration threshold for which significant effects in development can be measured. These results suggest maternal melatonin may influence embryonic developmental trajectories, & may ultimately affect offspring survival & fitness.

S9.8 SOARES, MC; CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, Universidade do Porto, Portugal; *marta.soares@cibio.up.pt*

The neurobiology of cooperation: the cleanerfish swim into the spotlight

Cooperation between humans represents one of the few spectacular exceptions in the animal world. Contrarily to most of other animal species, humans frequently cooperate with genetically unrelated conspecifics, often in large groups, with individuals they will never meet again, and when reputation gains are small or absent. One rare example of cooperation between unrelated individuals in a non-human model happens in the cleaner-client fish mutualism. The most notorious cleaner fish species Labroides dimidiatus has been a model system to study the evolution of cooperation between unrelated animals and between different species during the last couple of decades. The unique similarities between some components of human cooperation and the cleanerfish mutualism, and the fact that the latter is a well-established model system for behavioural studies of cooperation offered an outstanding opportunity to identify the link between cooperation, social cognition, and to undertake proximate studies which were severely in need. This review surveys the current achievements of several recent studies, and the potential of the cleanerfish mutualism as relevant model system for future accomplishments in neuroendocrine research.

S6.5 SOCKMAN, K.W.*; LYONS, S.M.; Univ. of North Carolina, Chapel Hill; *kws@unc.edu*

How song experience affects female mate-choice, male song, and monoaminergic activity in the songbird auditory telencephalon

A sexual signal can indicate not only the signaler's attractiveness as a potential mate but also the signaler's competitiveness relative to rivals. As the attractiveness or competitiveness of the prevailing signaling environment increases, individuals prospecting for mates should elevate their choice threshold, whereas competing individuals should shift resources toward elevating their own competitiveness. Through a series of experimental manipulations using laboratory-housed Lincoln's sparrows, we have discovered that females change the strength of their song preferences depending on the attractiveness of the song environment to which they have recently been exposed; compared to a less-attractive environment, a highly-attractive environment elevates the threshold for releasing phonotaxis behavior toward male song. We also discovered that males modulate the competitiveness of their own song behavior based on both the competitiveness of their current, adult environment and the competitiveness of the environment they experienced as juveniles. These behavioral adjustments in females and males are associated with changes in forebrain monoaminergic activity that are triggered by experimental manipulations of the attractiveness and competitiveness of the song environment. Findings from these studies suggest possible neural mechanisms for the regulation of adaptive behavioral plasticity associated with dynamic sexual signaling environments.

114.6 SODA, KJ*; SLICE, DE; Florida State Univ., Florida State Univ., Univ. of Vienna; *k.jamessoda@gmail.com*

Vector autoregressive-moving average models as tools to visualize differences in shape trajectories

One advantage of geometric morphometric methods (GMMs) is an ability to visualize data. Yet classical GMMs cannot fulfill all visualization needs. One example is shape trajectories, temporally-ordered sets of shapes. While GMMs can visualize comparisons between shapes within trajectories, visualizations to compare trajectories themselves are challenging. Here we introduce a method to visualize how two regularly sampled, globally stable shape trajectories differ. First, an autoregressive-moving average model is fit to each trajectory. These models describe how a shape relates to previous shapes in the trajectory, how a shape deviates from the other two components (i.e., the "shock"), and how a shape relates to previous shapes' shocks. Since the shocks are assumed to follow a normal distribution with mean zero, the shocks' covariance matrices are estimable. Next, the researcher creates two simulated trajectories. The first shapes in each are identical to one of the original trajectories' mean shapes, and the initial shocks are zero. The difference between the mean shapes is then visualized. Next, a shock for the next shapes in the simulations is drawn from a normal distribution with mean zero and one of the estimated covariance matrices. Based on this shock and the models, the simulations' next shapes are calculated and a comparison is visualized. The process of generating shocks, calculating new shapes, and visualizing comparisons continues for a desired number of shapes. Finally, each comparison is merged into an animation. The animation reflects the original trajectories as the simulations show roughly how the original trajectories would appear had the same conditions (i.e., shocks) influenced both. The merits and drawbacks of this method are discussed.

P2.54 SOMBATSAPHAY, V*; REITZEL, AM; UNC Charlotte; *vsombats@uncc.edu*

Structural and functional characterization of aquaporins from early diverging animal phyla.

Aquaporins are channel proteins that transport water and, sometimes, small solutes across membranes. Aquaporins have been shown to increase the movement of water by 10-fold the rate of passive diffusion, and are involved in important functions like cell volume regulation and maintenance of osmotic homeostasis. Despite the importance of aquaporins, little is known about the evolutionary history of aquaporins in animals, especially early diverging taxa that are all marine. Here we report on the phylogenetic diversity and relationship of aquaporins from four representative species, *Mnemiopsis leidyi* (Ctenophora), *Amphimedon queenslandica* (Porifera), *Trichoplax adherens* (Placozoa) and *Nematostella vectensis* (Cnidaria), with metazoan and single cell outgroups. We utilized heterologous expression assays to determine how phylogenetic identity relates to structure and function in these membrane proteins. Aquaporins from *Mnemiopsis*, *Amphimedon*, *Trichoplax* and *Nematostella* were cloned, expressed in *Xenopus* oocytes, and assayed for transport function of water, urea and glycerol. Aquaporins were predicted to have functions reflective of their phylogenetic relationship to related membrane proteins in bilatarian species whose structure and functions are known. Comparisons of protein sequence, phylogenetic relationship and function provide insight into the early evolution of these critical proteins.

37.6 SOMJEE, U*; MILLER, CW; DUELL, M; SOMJEE, Ummat; Univ. of Florida; *ummat.s@gmail.com*

The hidden costs of sexually selected weapons in the heliconia bug (Leptoscelis tricolor)

The diverse horns of African antelopes, massive tusks of elephants and the looming antlers of elk are all examples of animal weapons. The most exaggerated of these structures can arise from competition among males for mating opportunities. These large and exaggerated weapons pose a curious evolutionary question; what are the consequences of these weapons to the animals that bear them? Underlying large and obvious weapons are likely suites of hidden behavioral and physiological traits that allow these animals to carry and use these weapons. Further, little is known about the role that energetic costs of weapons play in behavior and mating patterns in wild populations. Here, we used a complementary set of laboratory and field studies to uncover the metabolic costs of sexual weapons in an exceptionally tractable insect system. First, we examine the consequences of large sexual weapons to the development of post-copulatory traits. Second, we perform detailed measurement of metabolic rate of insects with different weapon sizes to determine the metabolic cost of maintaining a large sexually selected trait. Finally, we follow individual insects in a wild population to reveal the relationships among weapon size and movement patterns in nature. Our findings suggest that large weapons impose many indirect developmental and metabolic costs to individuals, and these costs likely play a part in driving movement and mating patterns in nature.

P3.198 SOMMERS, AS*; ROGERS, EJ; MCGUIRE, LP; Texas Tech University, Lubbock; *amie.sommers@ttu.edu*

Phenotypic Flexibility in Body Composition of Brazilian Free-Tailed Bats

Organisms respond to variation in energy availability and demand by altering behavior, physiology, and morphology; collectively, this is called phenotypic flexibility. We studied Brazilian free-tailed bats (*Tadarida brasiliensis*) to assess phenotypic flexibility driven by intrinsic and extrinsic factors. *T. brasiliensis* are small, volant endotherms that experience wide variation in energetic demand. Crucially, males and females experience reproductive energy demands at different times of the annual cycle. Pregnancy and lactation occur during the summer while males undergo spermatogenesis over winter. Thus females face both intrinsic (reproductive) and extrinsic (environmental) challenges in summer. Males cope with the same environmental variation as females, but experience little intrinsic variation in summer. We hypothesized the *T. brasiliensis* phenotype (lean and fat mass) would vary in response to energy demand. We predicted greater variance in females due to greater and more variable intrinsic energy demand during the summer active season. We used quantitative magnetic resonance to measure body composition (lean mass, fat mass, total body water) of adult *T. brasiliensis* during the summer active period. To provide context to changes in lean mass, we collected bats to measure organ sizes, considering organs associated with digestion and exercise. Female total lean mass increased through pregnancy, and again through lactation, while fat mass decreased through pregnancy and lactation. There was little variation in lean and fat mass of males over the summer. Organ size analysis is ongoing. Our results suggest that intrinsic factors have a greater effect than extrinsic factors on the *T. brasiliensis* phenotype during the summer season.

P3.163 SOO, E.M.*; DEAROLF, J.L.; THOMETZ, N.M.; DUNKIN, R.C.; WILLIAMS, T.M.; NOREN, D.P.; HOLT, M.M.; Hendrix College, Conway, AR, Univ. of California, Santa Cruz, Northwest Fisheries Science Center, NOAA; *sooem@hendrix.edu*

Myosin heavy chain expression in cetecean vocal muscles

In order to generate sound, cetaceans (whales, dolphins, and porpoises) push air through their nasal passages and across their phonic lips. They are able to move the air necessary for phonation by contracting muscles that surround air sacs, which are associated with their nasal passages. While these muscles have been described anatomically, their contractile abilities remain unknown. In order to better understand the functional abilities of these muscles, the purpose of our study is to determine the myosin heavy chain protein composition in the left and right nasal musculature (anterior and posterior internus and externus and intermedius muscles), palatopharyngeal sphincter, and genioglossus complex of bottlenose dolphins (*Tursiops truncatus*) and harbor porpoises (*Phocoena phocoena*) using SDS-polyacrylamide gel electrophoresis. Myosin was extracted from the vocal/nasal muscle samples (~2.5 mg) of four dolphins and four porpoises, and aliquots of each myosin extract were electrophoresed at 275 V for 24-hours in 8% acrylamide, 30% (v/v) glycerol separating gels. Images of the silver stained gels were captured, and the staining densities of each myosin band in each sample were determined using ImageJ software. These values were converted into proportions of total myosin represented by each band in each sample and were used to calculate average proportions of each myosin isoform in the muscles of both species, which will allow us to compare the myosin expression patterns in these dolphin and porpoise muscles. Quantifying the myosin heavy chain protein expression in these vocal/nasal muscles will allow us to construct hypotheses about the contractile abilities of these muscles in cetaceans.

P3.130 SOSA, T*; BAJOR, M; University of Chicago, Loyoloa University of Chicago; *tims@uchicago.edu*

Projecting range expansions of Neotropical fishes in response to climate change

Characid fishes (New World tetras) have a South American origin, but colonized North America as part of the Great American Interchange. Here, we construct biologically grounded niche models for the northernmost species, and use projections for climate change across the North American continent to predict possible areas of range expansion under various disturbance scenarios. We find that relatively modest ecological differences among species lead to very different projections; in particular, generalist species are expected to expand northward more rapidly than either hypercarnivores or herbivores.

AMS.1 SOSIK, H.M.; Woods Hole Oceanographic Institution; *hsosik@whoi.edu*

Life in the Plankton, Stories from automated submersible microscopy and flow cytometry

This presentation will highlight vignettes that include parasitoid control of diatom blooms, dynamics of harmful algal blooms that threaten human health, sex and death in the plankton, and climate-related impacts on the phenology of picocyanobacteria. Marine microbial ecosystems are diverse, highly dynamic, and exert major influences on productivity and biogeochemistry across local to global scales. Yet, many aspects of how and why marine plankton communities change through time and space remain poorly understood, in large part because traditional organism-level sampling strategies are not amenable to high frequency, long duration application. The combination of ocean observatories and automated sensors is now addressing this gap and accelerating the pace of discovery. FlowCytobot, a submersible flow cytometer for laser-based particle measurements, and Imaging FlowCytobot, which includes integrated video imaging, are capable of rapid, unattended analysis of individual cells and colonies. Over a decade of high resolution observations in US coastal waters have provided measurements of 100s of millions of cells, which in many cases can be classified to genus or species with automated analysis. These taxon-specific, high resolution records are revealing extraordinary detail about the biology and dynamics of these "unseen" ecosystems.

24.5 SOTO, A*; MCHENRY, MJ; UC Irvine; *alberts2@uci.edu*

Prey targeting with intermittent locomotion in zebrafish

The strategies implemented by predators to track and capture prey vary widely among animals. Biologists have successfully applied mathematical models developed for missile guidance to determine the pursuit strategies of flying predators, such as dragonflies and bats. These models generally assume continuous motion, but many predators move through their environment in discrete bouts of activity, such as the beat-and-glide swimming of fishes. To understand how prey targeting is controlled in intermittent locomotion, we conducted predation experiments in zebrafish and developed a biomechanical control model that predicts the trajectory of a predator during hunting. We found that the predator's bearing angle during a glide is predictive of the yaw during the subsequent tail beat. Our control model consequently used the bearing angle as a control input to determine the thrust force, the control variable in our model. We found that proportional control is sufficient for approaching prey. However, intermittent swimming requires that the proportional response be delayed until the completion of a glide. This model provides a basis for understanding the sensory-motor mechanisms of a broad diversity of predators.

P2.22 SOUTHER, JL*; GUNDERSON, AR; PAGANINI, AW; TSUKIMURA, B; STILLMAN, JH; San Francisco State Univ., Romberg Tiburon Center, CalifornSan Francisco State Univ., Romberg Tiburon Centeria State University, Fresno, California State Univ., Fresno; *jsouther@mail.sfsu.edu*

The Effects of Increased Temperature and Density on Petrolisthes cinctipes Individuals Within Populations

The intertidal zone porcelain crab, *Petrolisthes cinctipes*, is likely to respond to increased abiotic stress (maximal habitat temperature) by moving lower in the tidal zone resulting in aggressive interactions with subtidal congeners. We aim to determine experimentally whether increased temperature causes *P. cinctipes* to move and to investigate the indirect effects on behavioral interactions. We hypothesize that crabs experiencing higher temperatures will see significantly higher injuries than crabs under less thermal stress. Tides and temperatures (8°C to 37°C) were taken from iButton data logger recordings at all tidal heights at the collection site in Fort Ross, California. Temperatures were used as-is for some treatments, and manipulated to reflect future climatic scenarios for other treatments. Reflecting field data, the female to male ratio is 4:6 and size ranges between 7-14mm distributed equally between treatments. Laboratory enclosures were built with high and low intertidal zones joined by a ramp allowing *P. cinctipes* crabs to move between zones. Injuries such as leg loss or exoskeleton scarring and mortality were monitored as an indicator for the indirect effects of temperature on behavior. Leg loss was observed most often. Observations showed *P. cinctipes* staying in the cool zone for treatments with higher temperatures and in both zones for low temperature treatments. Distribution changes and novel interactions have the potential to cause ecosystem-wide effects. A broader understanding of the combined effects of abiotic and behavioral stress will inform indirect behavioral responses of ectotherms to climate warming.

72.6 SPAAN, JM*; PITTS, N; EZENWA, VO; JOLLES, AE; Oregon State University, Corvallis; *spaanj@oregonstate.edu*

Acute infectious diseases drive stress in a wild mammalian population

Any organism unable to maintain homeostasis undergoes stress. Nutrition, anthropogenic disturbances and predation are all factors that have previously been shown to cause stress in wild mammals. In addition to disturbances directly linked to human contact (e.g., hunting, capture and handling) and habitat lost, the recent rise in reported infectious disease emergence in wildlife and in humans has raised global concern. While stress has been linked to increased disease susceptibility (cattle shipping fever, and colds/herpes in humans), whether infections actually contribute to physiological stress in animals is unknown. Quantifying the stress that an animal is experiencing thus represents an immediate measure of the physiological response to changes in its environment, and a prospective assessment of the animal's health and well being. Here we tested whether infectious diseases affected stress in a free-ranging population of African buffalo. We measured both acute and chronic infections by viral, bacterial pathogens and parasites. Acute, but not chronic infections were stressful. As well as low body condition, dry years and the mating season. This is to our knowledge the first study to show infectious diseases cause stress in a wildlife population; and that is important because it could set up a negative feedback cycle between stress and infectious diseases, putting already struggling populations at increased risk/reducing their viability.

145.4 SPAIN, D.*; SULLIVAN, L.; YOUNG, A.; SPAIN, Diara; Dominican University of California; *diara.spain@dominican.edu*
Developing Relevant Science Classes for Non-science Majors
A typical undergraduate student with a humanities or business major may take one or two science classes during their academic career to graduate. In many cases these classes are endured but not enjoyed by the students. We have used lemons to make lemonade by developing science classes targeting Honors Program students with non-science majors. In spring 2011 we began offering Aquatic Ecosystems of the Bay Area and in fall 2013 we began offering Bay Area Rocks: Geology of the Bay Area. These classes differ from the other science classes available to majors because the scientific content is explored, integrated, and interpreted with historical, current, and future issues. In addition to the content being relevant locally, these classes have a civic component which takes the students out the lab and into the community.

70.1 SPAINHOWER, KB*; METZ, AK; KIRALY, PM; BARKETT, EM; THOMAS, DR; CLIFFE, RN; BUTCHER, MT; Youngstown State University, Swansea University; *mtbutcher@ysu.edu*
Fiber Type Properties of the Limb Muscles of Sloths (Xenarthra: Pilosa)
Sloths exhibit under-branch suspension by one or more limbs for extended periods of time. Despite these abilities that require great strength, their skeletal muscle mass is low; however, their overall limb form has been extremely modified for suspensory behaviors. One modification may be the homogeneous expression of slow myosin heavy chain (MHC) isoforms in muscle fibers with high fatigue resistance. This hypothesis was tested using a combination of protein gel electrophoresis (SDS-PAGE) and histo/immunohistochemical analyses to determine fiber type properties in the limb muscles of two-toed (*Choloepus hoffmanni*, N=3) and three-toed (*Bradypus variegatus*, N=3) sloths. A primary expression of only slow MHC-1 and fast MHC-2A is observed in each species. Both fiber types are reactive for oxidative potential, and all muscles analyzed indicate a broader proximodistal distribution of slow, oxidative fiber types, except for the carpal/digital flexors. Slow MHC-1 fibers are larger in cross-sectional area (CSA) than fast MHC-2A fibers. In addition, we observed that sloth muscles appear to have appreciable extracellular matrix in between regions of contractile tissue. The findings do not match our hypothesis, and collectively, they suggest that sloths have evolved slower-contracting, fatigue resistant muscles for suspensory behaviors. The physiological properties observed (e.g., larger CSA for MHC-1 fibers) are further consistent with economical force production. However, while slow fiber type specialization provides a means to sustain muscle force, large forces that may be required for suspension are likely more dependent on muscle architecture and potentially, the passive versus active force properties of their muscles.

96.5 SPEARE, L; WOLLENBERG, M; MANDEL, M; MIYASHIRO, T; SEPTER, A*; Univ. of North Carolina, Kalamazoo College, Northwestern Univ., Penn State Univ.; *asepter@email.unc.edu*
Squid Symbionts Use a Molecular Syringe to Kill Competitors
Acquisition of beneficial symbionts from the environment is found throughout biology, yet little is known about how potential colonizers interact with one another during symbiotic initiation. We use the vibrio-squid symbiosis as a model system to understand how symbionts interact during the infection process to ultimately impact community structure in the host. Although a single species of bioluminescent bacteria (*Vibrio fischeri*) is found in the light organ of the squid, *Euprymna scolopes*, this light organ community is comprised of multiple, genetically distinct *V. fischeri* strains. Several "founder cells" can initiate colonization and expand their populations within the light organ, however certain strain combinations are incompatible and result in a one strain dominating within the host. We hypothesized that such strain-specific interactions are driven by genetic differences that allow symbiotic populations to compete for a narrow niche: the light organ. We developed a culture-based, co-incubation assay to explore strain-specific interactions of light organ symbionts and we observed two outcomes: coexistence where two different populations grew together without apparent inhibition, and competition where one population killed the other. Comparative genomics and targeted mutagenesis indicate symbionts use the type VI secretion system (T6SS), which acts as a molecular syringe, to inject lethal toxins directly into neighboring cells. Interestingly, these squid symbionts do not kill more distantly-related marine bacteria, but rather target other members of the Vibrionaceae family, which are the primary colonizers of this host-associated niche in fish and squid. These findings are the first evidence that symbionts actively kill competitor cells using a mechanism to specifically target populations that share the same niche.

47.6 SPECK, HP*; BURGESS, B; WILLIAMS, D; JACOBS, DK; Univ. of California, Los Angeles; *hspeck@ucla.edu*
Tip-links, Usher Syndrome and the Origin of Metazoan Mechanotransduction
Similarity of Metazoan mechano-sensory cells as well as sponge choanocytes has has led to inferences that such cells evolved from a common ancestral cell type. Usher syndrome (US) causes deafness and blindness in vertebrates, and the suite of genes characteristic of this syndrome are known to play key roles in mechanosensation. To explore the ancestry of function of these genes in the base of the metazoa we conducted a bioinformatic assessment across basal Metazoa and Eukarya. Having confirmed a variety of these genes through the base of the Metazoa we are conducting antibody work to examine the expression of US genes in *Aurelia*, a medusa bearing cnidarian sister to the better studied Bilaterian clade. Aurelia is one of the more basal taxa with discrete sensory structures including a statocyst associated with mechanoreceptors, cnidocyte sensory response and eyes. Hair cells project tightly packed ascending rows of microvillar "stereocilia" tip-linked to each other and to a cilium using the US1 subset of US genes. In *Aurelia*, immunofluorescence detected an association of the US1 gene Myosin VIIa in mechanosensory cells, associated with cnidocytes, known to be tip-linked in other Cnidaria. This strongly supports the common functional origin of mechanoreceptors through the base of the cnidarian Bilaterian clade. We hope to examine this general problem in greater detail across the sensory cell types found in *Aurelia*. More broadly biomedical syndromes provide a nexus of interaction that is potentially of substantial interest in an evolutionary context.

S11.2 SPEISER, D.I.; University of South Carolina;
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Function and evolution of the dispersed visual systems of bivalves and chitons

Compared to eyes that provide high spatial resolution (such as the paired cephalic eyes of many vertebrates, cephalopods, and arthropods), eyes that provide low spatial resolution have received relatively small amounts of attention from researchers. Here, using a diverse set of molluscan models, I will argue that low-resolution visual systems have much to teach us about the function and evolution of eyes. First, low-resolution eyes tend to be less complex overall than high-resolution eyes, but their apparent simplicity can mask unique or sophisticated features. The eyes of scallops, for example, form images using unique, mirror-based optics and sample these images with two separate retinas. In addition to these uncommon structural features, we are accumulating evidence that the eyes of scallops are dynamic structures that change shape in response to different environmental conditions. Second, we find that many animals with low spatial resolution vision have a multitude of eyes, but we know very little about the neural processing that underlies these dispersed visual systems. In the case of scallops, how do animals process the images gathered separately by their dozens to hundreds of eyes? Do they integrate information from multiple eyes so that a single reconstruction of their visual environment is formed? Third, a phylogenetic perspective on the distribution of light-detecting structures across taxa suggests that low-resolution visual systems may have evolved relatively recently in certain groups. These groups represent promising opportunities for using comparative molecular techniques to study how eyes may evolve from non-eye structures. To illustrate this point, I will discuss how we are using the distribution of different light-detecting structures across chitons (Mollusca: Polyplacophora) to reconstruct a step-by-step account of how and why eyes evolved in certain taxa within this group.

P2.272 SPIEGEL, LA*; FREEMAN, AS; Adelphi University;
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The effect of salinity on Loxothylacus panopei nauplii mortality

Loxothylacus panopei is a rhizocephalan parasite that infects marine, panopeid mud crabs such as *Rhithropanopeus harrisii* and *Eurypanopeus depressus*. The life cycle of the parasite is complex and may be influenced by environmental factors at key stages in its development. In the first stage, as non-parasitic nauplii, *L. panopei* is more susceptible to changes in salinity than at other stages in the life cycle. The purpose of our experiment was to expand upon previously tested salinities to determine the survival of *L. panopei* nauplii across a full range of salinities. The nauplii were exposed to increasing water salinities in increments of 5 ppt in a range of 5-30 ppt. Over a one-week period, nauplii mortality was recorded until all metamorphosed into cypris or perished. Our analysis determined that nauplii survived better at high salinities.

71.4 SPRAYBERRY, JDH; Muhlenberg College;
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Investigating the fidelity of learned odor cues in bumblebees

Observations of floral constancy in bumblebees imply that foraging bumblebees are capable recognizing target flowers from a noisy background of non-target flowers. Indeed, making a target flower more recognizable by increasing its variability from background flowers increases bumblebees' tendency to exhibit floral constancy. Floral recognition is driven by sensory cues such as shape, color, and/ or floral odor. Bumblebees have a demonstrated ability to associate odor cues with a profitable resource: using odor to locate food in a maze, and successfully conditioning to odor cues in Pavlovian experimental paradigms. Our prior work showed that olfactory pollution has a negative effect on bumblebee foraging behavior in a laboratory study that utilized two representative agrochemical odors. This small stimulus set indicated that olfactory pollution can impact behavior, but did not allow us to determine if the structural relationship of the contaminating odor signal relative to the original associative scent drove the observed behavioral changes. This begets the question, does the level of structural similarity between the associative (A) and contaminating (B) odors impact the likelihood of disrupting an olfactory association? Current experiments train bumblebees to associate a floral odor blend with a sugar reward, then offer foragers a choice between an uncontaminated feeder (scented with A), and a contaminated feeder (scented with AB). Using RFID, we are able to track individual foragers' behavioral responses to odor contamination. In addition, GCMS characterization of associative and contaminating odor-blends allows us to look for correlations between behavioral responses and the structure of polluting odors. Preliminary analysis indicates that effects of contaminating odors are not universal.

104.1 SRYGLEY, RB*; BRANSON, DH; USDA-Agricultural Research Service; *robert.srygley@ars.usda.gov*
Predator or Competitor? A Seemingly Benign Interaction and Its Effects on Immune Function

Mormon crickets *Anabrus simplex* are well known for their carnivory, which effectively drives their migration in a well-organized common direction when densities are sufficiently high. Carnivorous behavior derives from a lack of protein in their diet, with those lacking protein also having less phenoloxidase (PO) available to combat foreign invaders and lower immunity to fungal pathogens. In addition to feeding on plants, Mormon crickets predate invertebrates, and we hypothesize that invertebrate prey availability determines the amount of protein in their diet. Because Mormon crickets commonly occur with grasshoppers that feed on the same plants, we investigated interactions between grasshoppers and Mormon crickets. If Mormon crickets are principally predatory on grasshoppers then grasshopper abundance could influence Mormon cricket immunity due to the role that protein availability has on circulating PO. In a field setting, we varied densities of Mormon crickets (0, 10, or 20 per cage) and grasshoppers *Melanoplus borealis* (0, 15, 30, or 45) in 68 1-m2 cages and measured survivorship. In addition, we measured dietary preferences and PO activity of Mormon crickets. We also measured Mormon cricket consumption of grasshoppers in a laboratory setting. In the field, both grasshopper and Mormon cricket survivorship declined with Mormon cricket density. Mormon cricket predation on grasshoppers and cannibalism were frequently observed. As predicted, diet preference shifted from protein to carbohydrates as grasshopper density increased, and PO activity also increased with grasshopper availability. Grasshoppers can be an important source of dietary protein for Mormon crickets, with grasshopper availability affecting Mormon cricket immunity to disease.

P1.165 ST. MARTIN, J*; STOEHR, A; AALBERS, S; SEPULVEDA, C; BERNAL, D; Univ. of Massachusetts Amherst, Univ. of Massachusetts Dartmouth, Pfleger Institute of Environmental Research, Pfleger Institute of Environmental Research; *jstmartin@umass.edu*

Thermodynamic Equilibrium in Free-Swimming Swordfish

Swordfish (*Xiphias gladius*) are large pelagic predators known for their capacity to undergo extensive diurnal diving movements. Swordfish, like tunas and lamnid sharks, have internalized aerobic red, locomotor muscle (RM) and retia, albeit simplistic; this suggests that swordfish are capable of regional endothermy, or at the very least capable of modulating heat transfer rates during vertical movement. This study used data obtained from modified archival tags that allowed the simultaneous measurement of ambient and deep-body (e.g., RM) temperatures to examine the rates of heat balance (i.e., body cooling and warming) in free swimming swordfish (n=6). Newtonian heat transfer models in which the whole-body thermal conductivity of swordfish (k), was constant, variable, or variable based on water and swordfish body temperatures were used to assess changes in heat balance during descents, ascents, and surface intervals. While the models adequately described differential heating and cooling rates for dive and surface intervals, the best-fit model was largely dependent on swordfish behavior (e.g, deep diving, basking, surface oriented). Although, K values obtained in this study were within the range of those for other endothermic fishes, swordfish RM appears capable of operating at very low temperatures for prolonged periods of time. Future work will develop more complex heat transfer models that incorporate a suite of important parameters that directly affect heat transfer (i.e. heat exchanger efficiency, bulk blood flow, metabolic heat production) to assess the potential ability of swordfish to physiologically thermoregulate.

P1.17 STAAB, KL; McDaniel College; *kstaab@mcdaniel.edu*

Implementation of 3D analysis and MakerEd practices for teaching vertebrate morphology to undergraduates

The decreasing costs of technology and increasing accessibility of digital materials has led to a "maker movement" from which higher education can benefit. Makers range from being formally trained engineers to at-home hobbyists and the convergence of their open-source materials (e.g., instructional videos, source codes, and 3D surface files) is valuable for diverse undergraduate classrooms. Furthermore, there are several online repositories for CT scans of animals, which students can use for not only visualizing anatomy, but also downloading files for 3D printing. MakerEd initiatives have led to increased confidence among K-12 students, similar to results from problem-based learning methods at the college level. Here, I provide examples of MakerEd approaches that make use of the valuable online resources to teach vertebrate morphology to students in introductory biomechanics and comparative anatomy courses. Self-guided research projects in an introductory biomechanics course include the requirement to build a physical model of animal anatomy, after learning about examples of biomechanists using models to test hypotheses about animal function. Manipulation of bones in 3D software aids students in visualizing and learning anatomical structures that might otherwise be confused in 2D illustrations in a comparative anatomy laboratory manual. Digital and 3D printed bones of extinct taxa strengthen students' understanding of key concepts in vertebrate evolution. In both courses, access to 3D technology, gadgets, and tools, in conjunction with discussions of primary literature, has led to increased engagement in undergraduates learning vertebrate morphology.

87.2 STAGER, M*; CHEVIRON, ZA; University of Montana; *maria.stager@umontana.edu*

The Time Course of Avian Physiological Adjustments to Cold Temperatures

For birds resident to the North Temperate Zone, preparing for and surviving winter is considered one of the most difficult parts of the annual cycle. Previous work has documented that in response to cold winter temperatures, residents alter much of their morphology and physiology, including enlarging their pectoralis muscles, enhancing vascular oxygen transport, and upregulating portions of their fatty acid transport pathway. Nonetheless, the time course over which these changes occur remains unknown. For instance, do they all occur simultaneously in response to the onset of cold temperatures or are they made incrementally in response to increasingly long periods of cold? To determine the progression and rate at which individuals adjust their physiology in response to cold temperatures, we performed an acclimation experiment to assay a large suite of physiological parameters across time. We captured Dark-eyed Juncos, *Junco hyemalis* (n = 60), and, after a six-week adjustment period, exposed individuals to one of two temperature treatments (-8°C and 18°C) for up to 8 weeks. We quantified metabolic parameters and body composition before and after treatments for each individual. We also longitudinally assessed physiological parameters by terminally sampling 5 individuals/treatment at 1, 2, 3, 6, and 8 weeks and quantifying a suite of traits (e.g., blood-oxygen parameters, organ size, enzyme activities). Additionally, we collected tissues for transcriptomic assays to assess the time-scale on which regulatory changes are occurring. Our results shed light not only on the mechanisms underlying seasonal phenotypic flexibility, but also indicate how species may be able to cope with short-term extreme weather events, which are predicted to increase in frequency in the near future.

S11.11 STAHL, Aaron; COOK, Tiffany A; BUSCHBECK, Elke K*; University of Cincinnati, Wayne State University; *elke.buschbeck@uc.edu*

A complex lens for a complex eye: lens composition in diving beetle larval eyes

Complex visual function relies on the ability to properly focus light onto the retina. Arthropods exhibit a wide range of eye types, yet little is known about how the lenses from these animals are composed. One hypothesis is that highly sophisticated eyes with high acuity vision develop/require more complex lenses than do simple eyes with lower resolution. To test this hypothesis, we performed mass spectrophotometry and transcriptome analysis from the lenses of two distinct arthropod visual systems: the adult compound eye of *Drosophila melanogaster* and the bifocal lens from the sophisticated principal larval eyes of *Thermonectus marmoratus*, an effective visually guided predator which simultaneously focus two images onto two retinas. In both species, the main constituents of the lenses were co-opted genes from the cuticular protein family. However, in *Drosophila*, only 4 lens proteins were identified, while in *Thermonectus*, 11 were defined. *In situ* hybridizations of these genes revealed differential expression within the lens producing (corneagenous) cells in both species. Most notably, however, the expression patterns in *Thermonectus* suggest that the composition of lens proteins differs between the periphery and the center of the bifocal lens, a distribution consistent with our functional studies that suggest that the periphery of the lens is optically different from its center. This study illustrates that a more complex lens is formed by a larger number of proteins than a simpler lens, and provides an example in which an extraordinary lens has evolved by altering expression patterns of genes.

143.4 STAHLSCHMIDT, ZR*; MILLS, AM; WALMAN, RM; Univ. of the Pacific, Low Country Institute; *zstahlschmidt@pacific.edu*

Dynamics influencing refuge use by vertebrate communities on the coastal plain—from seasonality to fire ants

Many animals utilize refuge to avoid predation, buffer themselves from ambient conditions (e.g.,to improve thermoregulation), or both. Yet, the decision to use refuge is complex and can vary due a range of factors—from species-specific life histories and interspecific interactions to time and abiotic factors. Thus, we surveyed terrestrial vertebrate communities under four arrays of artificial cover objects (n=108 cover boards) 1-2 times per month for two years in Beaufort County, S.C. while accounting for temperature, season, and habitat characteristics (e.g., canopy cover and distance to nearest edge). In the second year of surveying, we excluded the red imported fire ant (*Solenopsis invicta*) from half of the cover boards across all arrays via regular administration of Amdro® to determine how this prominent invasive species influenced the community dynamics of refuge use. We observed nearly 1,300 individual vertebrates spanning 18 genera and all four classes of terrestrial vertebrates. We will present results related to how increasingly relevant abiotic and biotic factors (e.g., temperature and invasive species, respectively) influence animal abundance and the biodiversity of communities across seasons.

P1.27 STANHOPE, ME*; GANDLER, HI; SHEA, DN; PASCUAL, MG; YU, A; LAMEYER, TJ; RONCALLI, V; CIESLAK, MC; DICKINSON, PS; CHRISTIE, AE; Bowdoin College, Univ. of Hawaii, Manoa; *mstanhop@bowdoin.edu*

Hormonal modulation in the lobster cardiac neuromuscular system: A transcriptomic analysis of peptide receptors in cardiac ganglion and muscle

Peptides are important modulators of neural circuit activity. In central pattern generator (CPG)-effector systems, peptides allow for flexibility in rhythmic motor output. In the lobster, *Homarus americanus*, the cardiac neuromuscular system, which consists of the cardiac ganglion (CG) and cardiac muscle (CM), controls the rhythmic motor output of the heart. This system is subject to modulation by both intrinsically and extrinsically-released peptides. Extrinsic peptides can be locally released from input fibers projecting to the CG from somata located elsewhere in the nervous system or can be delivered to CG and/or CM hormonally via the hemolymph. To investigate hormonal signaling in the cardiac neuromuscular system, we generated CG- and CM-specific transcriptomes, which were mined for peptide receptor-encoding sequences, specifically those for peptides known to be present in the sinus gland and/or pericardial organ, two neuroendocrine organs. Receptors for seven peptide families were identified, with some receptors restricted either to the CG (crustacean cardioactive peptide, red pigment concentrating hormone, and tachykinin-related peptide) or CM (pigment dispersing hormone), and others found in both tissues (allatostatin-C, myosuppressin, and proctolin). These data suggest that some peptides may have different sites of action within the cardiac neuromuscular system. Supported by: NSF (IOS-1353023, IOS-1354567, OCE-1459235), NIH (8P20GM103423-12), Cades Fdn., UHManoa's Undergrad Res. Opp. Prog., APS Undergrad Res. Fellowship, Doherty Fdn./Bowdoin Coll.

59.4 STANNARD, HJ*; MCALLAN, BM; RAUBENHEIMER, D; University of Sydney; *hayley.stannard@sydney.edu.au*

Macronutrient intake in carnivorous marsupials

Macronutrient composition plays a role in food intake of carnivores, in the wild and in captivity. Research has shown species such as dogs (*Canis lupus familiaris*) target for high fat diets, while cats (*Felis catus*) and mink (*Neovison vison*) target for high protein and moderate fat diets. The largest extant Australian marsupial carnivore, the Tasmanian devil (*Sarcophilus harrisii*) and one of the smallest, the fat-tailed dunnart (*Sminthopsis crassicaudata*) have been studied to determine their macronutrient preferences. Preliminary analysis has shown devils prefer protein while dunnarts prefer fat. Their choices can be related to their dietary preferences and physiological/behavioural processes.

86.1 STARK, AY*; YANOVIAK, SP; University of Louisville, University of Louisville ; *alyssa.stark@louisville.edu*

Slippery When Wet: Adhesion and Running Velocity of a Tropical Canopy Ant on Wet Substrates

Wingless ants foraging in the tropical rainforest canopy must cling and run along substrates such as leaves, vines and bark. However, tree crowns offer little protection from sun, wind, and rain, creating a complex and challenging environment for the tiny adhesive pads of an ant. Here we explore how two common environmental features of the tropical canopy, substrate wettability (hydrophobicity) and rain, affect the static and dynamic adhesive performance of a common tropical canopy ant (*Cephalotes atratus*). We found that *C. atratus* workers exhibit higher shear and normal adhesion on intermediately wetting substrates. The addition of surface water droplets (resembling rain) did not affect normal adhesion, but shear adhesion was reduced. Running speed was lower on all wet substrates. Finally, we investigated adhesion to a less controlled but more ecologically relevant substrate: wood. We found that normal and shear adhesion differed among dry, misted and water-soaked wood, and generally reduced running speed. Here we provide the first quantitative assessment of tropical canopy ant adhesive performance across conditions that approximate those encountered in the canopy.

P1.233 STARK, AY; PALECEK, AM*; ARGENBRIGHT, CW; BERNARD, C; BRENNAN, AB; KLITTICH, MR; NIEWIAROWSKI, PH; DHINOJWALA, A; The University of Louisville, The University of Akron, University of Florida, University of Florida; *amp129@zips.uakron.edu*
Gecko Adhesion on Wet and Dry Rough Substrates
The gecko adhesive system has been studied on a variety of smooth, dry, artificial surfaces. However, geckos are likely to encounter variably rough surfaces in their natural habitat, such as leaves and bark, and these surfaces may often be wet due to rain or high humidity. Previous studies have suggested that intermediary roughness reduces adhesion, and that substrate wettability must be more hydrophobic for geckos to maintain their grip. Although many studies have addressed gecko adhesive performance on rough substrates, none have considered how substrate roughness and surface water affect adhesion jointly. To investigate this interaction, we measured gecko adhesion on large-scaled and fine-scaled rough substrates that varied in wettability in air and in water. We found that there was no significant difference in adhesion on large-scaled rough substrates in air, but there was a significant decrease in adhesive performance on these hydrophobic surfaces in water. Conversely, on the fine-scaled substrates, there was a significant increase in adhesive performance in air, but there was no significant difference in adhesion in water. The results of this study have significant implications for how geckos navigate their natural environment in more complex conditions.

99.2 STAYTON, CT; Bucknell University; *tstayton@bucknell.edu*
Methods for Combining Multiple Multivariate Performance Surfaces to Explain Patterns of Phenotypic Diversification
Performances surfaces are representations of the relationship between phenotype and performance in a particular function. They are often employed to explore patterns of phenotypic diversification. However, many structures perform multiple functions and are associated with multiple performance surfaces. There is no consensus regarding methods for combining multiple performance surfaces in diversification analysis, partially due to the difficulty of determining how to weight performance surfaces. I present three methods for combining performance surfaces, none of which require known estimates of the relative importance of functions. Performance surfaces can be used to identify regions of phenotypic space in which simultaneous increases in performance for all functions are possible, and hence where species are not expected to occur. They can be used to identify functional "ridges" along which organisms are expected to occur, for all possible relative weights of different functions. Finally, they can be used to estimate the relative importance of various functions for individual species, as well as the amount of variation which cannot be explained by performance for any of the functions under consideration. These techniques are illustrated on shell shape data for 261 species of turtle and performance surfaces for shell strength and hydrodynamics. The surfaces predict the distribution of turtles fairly well, but only approximately 30% of shell shape variation is explained by performance on these two functions. The combination of performance surfaces has enormous potential, not only for determining whether certain functions have influenced patterns of phenotypic diversification, but also for illustrating which aspects of variation remain unexplained by functional performance.

S11.5 STöCKL, Anna*; O'CARROLL, David; WARRANT, Eric; Lund University; *anna.stockl@biol.lu.se*
Hawkmoths sacrifice spatial resolution to increase sensitivity in dim light.
The visual systems of many animals, particularly those active during the day, are optimised for high spatial resolution. However, at night, when photons are sparse and the visual signal competes with higher levels of noise, high spatial resolution cannot be sustained since it is traded for the higher sensitivity required to see in dim light. High spatial acuity demands detectors and successive visual processing units whose receptive fields cover only a small area of visual space, in order to reassemble a finely sampled and well resolved image. However, the smaller the sampled area, the fewer photons can be collected, and thus the worse the visual sensitivity becomes - leading to the classical trade-off between sensitivity and resolution. Nocturnal animals usually resolve this trade-off in favour of sensitivity, and thus have lower spatial acuity than their diurnal counterparts. We have recently shown that in dim light nocturnal hawkmoths spatially sum information from neighbouring visual processing units, thus increasing sensitivity and reducing spatial resolution in their motion vision system. Here, we compare several hawkmoth species with different diel activity patterns, to study to what degree species with different sensitivity requirements trade-off spatial resolution in favour of sensitivity, and at which stages of their visual system this trade-off occurs.

46.1 STECK, M*; RONCALLI, V; CIESLAK, M; LENZ, P; CHRISTIE, A; PORTER, M; University of Hawaii at Manoa, PBRC; *steck4@hawaii.edu*
Characterization of Phototransduction Genes in Alima pacifica (Crustacea, Stomatopoda)
Adult stomatopods have complex eyes that are specialized for color and polarization vision. Up to 16 different photoreceptors and as many as 33 expressed opsin transcripts are active in the visual system of adult stomatopods, presenting unparalleled opsin diversity within an individual animal. Whether this diversity exists in the larval stomatopod eye as well has yet to be studied. During development, larval stomatopod eyes rapidly transition from a simple compound eye to a double-retina stage, in which the larval retina and adult retina coexist, before the larval retina degrades and the adult retina is completed. The adult eye of the stomatopod has three sections; dorsal and ventral lobes divided generally by six rows of enlarged ommatidia. In contrast to other stomatopod species, *Alima pacifica* have only two midband rows; this reduced adult eye allows us to elucidate relationships between eye development, complexity, and related molecular components. We analyzed retinal transcriptomes of *A. pacifica* adults and last-stage larvae with double retinas, with larval and adult retinal tissues separated by dissection prior to analysis. RNA sequencing was performed using the Illumina platform and raw reads were assembled in Trinity. Phototransduction genes were identified using Phylogenetically-Informed Annotation. Eight opsins expressed in larval tissue and 10 opsins expressed in developing adult retinal tissue. Multiple transcripts for other phototransduction components were also found. These data support previous hypotheses that opsin gene duplication events in stomatopods have occurred recently and frequently. Despite having only two midband rows, the level of complexity in the phototransduction pathway of *A. pacifica* is higher than the characterized number of photoreceptors would suggest.

68.5 STEELE, AL*; WARNER, DA; Auburn University;
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Sex-specific Effects of Incubation Temperature on Morphology, Performance, and Growth in a Lizard with Environmental Sex Determination

The developmental environment plays a pivotal role in shaping phenotypes and fitness of all organisms. Perhaps the most enigmatic example of environmental effects is the influence of developmental temperature on an individual's sex, a phenomenon known as temperature-dependent sex determination (TSD). The first description of TSD was based on a study conducted 50 years on an African lizard (Agama agama). Although novel at this time of publication, this landmark study consisted of low sample sizes and provided a poor description of the sex-determining reaction norm in this species. Our goal was to revisit this work and better characterize the pattern of TSD in A. agama. In addition, we aimed to quantify the effects of constant and fluctuating incubation temperatures on a variety of fitness-relevant traits of offspring. Eggs were obtained from an invasive population of A. agama in Miami, FL, and randomly assigned to one of nine incubation treatments: six constant temperature treatments and three fluctuating treatments that mimic field conditions. We then measured hatchling morphology (snout-vent length, head size, mass), growth, and sprint performance as indicators of fitness. Size measurements will be continuously taken every six weeks to determine the ontogenetic timing of sexual dimorphism and to determine if sexual dimorphism is influenced by incubation temperature. Preliminary data suggest that warm incubation temperatures produce mostly female offspring. This ongoing research will provide a critical evaluation of the long-term effects of developmental temperature on fitness-relevant traits, and provide insights into the adaptive significance of TSD.

P3.65 STEELE, T*; ZORNIK, E; Reed College; *thesteel@reed.edu*
Rapid masculinization of the vocal central pattern generator of the frog, Xenopus laevis

African clawed frogs (*Xenopus laevis*) produce mating calls driven by a central pattern generator (CPG). Calls are sexually differentiated, and male courtship vocalizations require circulating androgens. Previous work has shown that ovariectomized female Xenopus develop the male-typical fast trill call after approximately 8 weeks of testosterone (T) treatment. To assess the timing of testosterone-induced masculinization, we studied T-treated female calling at 2 week intervals over 10 weeks. Call rates masculinized gradually over the testing period. We also recorded "fictive vocalizations", laryngeal nerve activity corresponding to vocalizations, from an isolated brain preparation in which the vocal CPG can be activated. Eight and ten weeks post treatment, females produced sustained calling rates of 42-55 Hz, slightly below the normal range of male calling, and fictive calling rates of 40-62 Hz, comparable to in vivo results. We found male-like vocal patterns *in vivo* (~37 Hz), and *in vitro* (~23 Hz) as early as 2 weeks post treatment, indicating a rapid masculinization process. In males, local field potential (LFP) recordings in the premotor nucleus during fictive vocalizations show a "wave" of activity coinciding with each call that persists when the premotor nucleus is surgically isolated from the rest of the CPG. These LFP waves were observed in T-treated female brains 2-4 weeks post treatment in intact and separated CPGs. While LFP waves were not observed in intact brains of control females, we recorded LFP waves in the isolated premotor nuclei of a control female. This result indicates that elements of the male vocal CPG are present in females, but may be functionally distinct due unique network properties of the female CPG. Our data collectively demonstrate that testosterone induced changes to adult female vocal circuits can occur within 2 weeks, potentially driven by altered synaptic properties.

120.1 STEFFENSON, M.M.*; BROWN, C.A.; Adams State University, Tennessee Technological University;
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Leg Autotomy and Its Effects on Predator-Prey Interactions in the Wolf Spider Pardosa valens

There are a variety of different factors that can influence the outcome of predator-prey interactions. One factor that has received little attention is how physical impairment can influence the ability of prey to survive predation events. In this study, we aimed to identify how a specific type of physical injury common to wolf spiders, autotomy, can influence how capable prey are at surviving predation. We further aimed to ascertain whether wolf spiders could use predator chemical cues to alter their behavior and possibly avoid consumption. Female predatory *Rabidosa santrita* wolf spiders were captured and allowed to deposit chemical cues in half of the foraging arenas for three days prior to all predation trials. Females of the smaller prey species (*Pardosa valens*) were captured and then brought back to the laboratory. If eggs sacs were present they were removed, and half of the *P. valens* had a randomly chosen leg IV removed. *P. valens* were then allowed 24 hours to acclimate to laboratory and physical impairment conditions. Prey were then placed in Tupperware arenas (half of which contained chemical cues, and half of which did not) and allowed to acclimate for an additional one hour before the introduction of the *R. santrita* predators. Containers were checked at predetermined intervals for prey mortality for a total of 24 hours. Data analysis indicates the loss of a leg did not significantly affect the ability of a prey spider to survive an encounter with a larger *R. santrita*, perhaps because *P. valens* have the ability to compensate for such injuries. When predator cues were present, both intact and autotomized *P. valens* survived longer than when cues were not present. This indicates that prey spiders may use chemosensory information from their environment to alter their anti-predator behavior.

92.2 STEIN, LR*; HUGHES, KA; HOKE, KL; Colorado State University, Florida State University; *lrstein@colostate.edu*
Behavior, morphology and life history traits show extensive heterosis and parent-of-origin effects in Trinidadian guppies

How a trait responds to selection depends not only on its variance, but on its covariance with other traits also under selection. Understanding the genetic basis of trait covariation can provide key insights into how suites of correlated traits diverge across populations. We used Trinidadian guppies (*Poecilia reticulata*) to explore covariation in divergent traits. Morphology, life history, and antipredator behaviors have undergone parallel evolution in multiple river systems as high-predation ancestors colonized sites with low predation intensity. We generated genetically diverse families by creating hybrid-inbred lines. We first crossed high- and low-predation populations from the same drainage with the potential to interbreed in nature, and then bred the resulting hybrid siblings together for two generations. We measured size, color pattern, brood size, and antipredator behaviors over 3 generations. As expected, F2 hybrids showed intermediate antipredator behavior between parental populations. Cross direction yielded striking asymmetries in the behavior of F2 fish, such that antipredator behaviors were more similar to the cross's maternal ancestral population. Covariation among behaviors was also influenced by cross direction: crosses between the maternal high-predation and paternal low-predation population had weakened correlations between behaviors compared to the other cross types. Further, many traits in this cross direction showed values outside the range of the parent populations (heterosis). Our results suggest that parent-of-origin effects play a large role in the expression of suites of divergent traits in Trinidadian guppies. This flexibility in trait covariances suggests that complex genetic influences on phenotypic covariances may shape parallel evolution of life history, behavior, and morphology.

108.1 STEINBERG, DS*; LEAL, M; University of North Carolina at Chapel Hill, University of Missouri, Columbia; *lucypenn@email.unc.edu*

An Unexpected Case of Homing in a Territorial Lizard

Homing is common in species that travel back and forth between different patches of habitat. However, one might not expect to find this behavior in species characterized by territoriality and limited dispersal. Here we report on experimental homing behavior in *Anolis gundlachi*, a territorial lizard endemic to the mountainous rain forests of Puerto Rico. Wild, male *A. gundlachi* returned to their territories when experimentally displaced 40, 80, or 120m in a random direction and without access to local cues. Some individuals were tracked using radio-telemetry and homed within 24 hours of displacement, along nearly straight paths to their destinations. The directness of the routes, coupled with the results of a computerized random walk simulation, suggests that lizards do not return to their original perches merely by chance. However, an initial series of experiments failed to identify the mechanism(s) underlying homing behavior in this species. Specifically, the removal of polarized light cues to the parietal eye and the disruption of localized magnetic fields did not reduce the probability of homing from 40m. Future work is needed to determine whether these results hold for greater displacement distances. Regardless of the homing mechanism, we argue that the ability of *A. gundlachi* to home despite the extraordinarily low probability of ever finding themselves such distances from their territories likely reflects both the value of territory ownership and strong selection for spatial memory in species that live in complex three-dimensional habitats. If true, homing ability may be more common than current empirical evidence indicates.

58.4 STEINWORTH, BM*; MARTINDALE, MQ; University of Florida Whitney Laboratory; *bsteinworth@ufl.edu*

Homeobox Genes in the Upside-Down Jellyfish Cassiopea xamachana

Homeobox transcription factors control body patterning across the diverse array of bilaterian body plans. As sister group to the Bilateria, Cnidaria provides an important evolutionary framework for understanding the evolution of body plans and the genes that pattern them. Hox and ParaHox gene homologues have been identified in the hydrozoan *Hydra* and in the anthozoans *Nematostella vectensis* and *Acropora digitifera*. The complete gut of bilaterians defines the anterior-posterior axis patterned by Hox and ParaHox genes, but how do these genes pattern a body that lacks anterior-posterior directionality? Hox genes have been shown to pattern the oral-aboral axis in the polyp form of hydrozoans and anthozoans, but their role is still unclear in the scyphozoan transition from polyp to medusa body plan, a process known as strobilation. Scyphozoan polyps may also bud off football-shaped propagules, which swim using cilia along the oral-aboral axis, similar to planulae, and metamorphose into new polyps. Strobilation and propagule-budding may even occur simultaneously in the same polyp. Here we investigate Hox genes in the upside-down jellyfish *Cassiopea xamachana*. Starting with adult, sexually mature medusae, our lab has facilitated settlement of planulae, strobilation of polyps, and growth of ephyrae into medusae, allowing investigation of Hox expression in all life stages and body forms of the animal.

P2.168 STEPHEN, C*; MIRE, P; Univ. of Louisiana, Lafayette; *cas7177@louisiana.edu*

Employment of Hair Bundle Mechanoreceptors on Tentacles of the Sea Anemone Nematostella vectensis in the Detection and Capture of Benthic Prey

The starlet sea anemone, *Nematostella vectensis,* has emerged as the model sea anemone for its fully sequenced genome, astounding regenerative properties, and speedy reproduction. The sea anemone's tentacles are covered in hair bundles, which are mechanoreceptors. Anemone's mechanoreceptors are used in the detection and capture of swimming prey. This study addressed whether or not hair bundle mechanoreceptors are used in the detection and capture of benthic, or crawling, prey. *Nematostella vectensis*' body column is submerged with tentacles exposed at the sediment layer. Therefore, this animal would likely benefit from capturing prey along the sediment layer. Experiments were conducted using the annelid worm *Tubifex tubifex* as benthic prey for individual anemones in petri dishes. Assaying the amount of time required to both capture and ingest the worms, while mechanoreceptors were both functional and inhibited by Streptomycin, showed that the mean time to capture benthic prey in the presence of mechanoreceptor inhibition significantly increased. Ingestion time, however, was unaffected. These results suggest that hair bundle mechanoreceptors on anemone tentacles are employed in the detection and capture of benthic prey. In order to study the viability of benthic prey versus swimming prey in a more natural habitat, ongoing experiments test prey capture by anemones in dishes containing sand in which they are partially buried. In order to test if the diffusible chemicals required to stimulate hair bundle elongation, which facilitate prey capture in the sea anemone, are also present in the worms, ongoing experiments involve measuring hair bundle lengths after exposure to worm-inhabited seawater compared to control seawater.

P1.146 STEPHENS, EZ*; POWERS, DR; George Fox Univ., Newberg, OR; *estephens13@georgefox.edu*

Does Poor Feeder Maintenance Increase Exposure of Hummingbirds to Pathogenic Bacteria and Fungi?

Due to widespread use, artificial feeders have become important food sources for hummingbirds. The high sucrose concentration of feeder solutions and poor feeder care provide an ideal environment for microbial proliferation, potentially increasing infection risk for hummingbirds. In order to characterize microbial growth in feeders we analyzed feeder-solution samples taken over a period of days at two different sites (Chiricahua Mts, SE AZ and Newberg, OR), measuring both microbial diversity and abundance. In addition, we analyzed microbial samples from the bills and tongues of Blue-throated (*Lampornis clemenciae*), Black-chinned (*Archilochus alexandri*), and Magnificent (*Eugenes fulgens*) hummingbirds using the feeders. Microbial abundance in feeders at the cooler Newberg site was significantly lower than those in warmer SE AZ, although both showed an increase in abundance over time. Growth patterns at both sites suggest temperature dependence. Microbial loads found on male hummingbirds were higher than females except for black-chinned where females exhibited the highest abundances measured. Microbial diversity was generally higher in males with female black-chinned showing the lowest diversity. Feeder visitation rate did not correlate with either microbial abundance or diversity. Since many black-chinned females were likely nesting it is possible that nesting behavior influenced our results. Feeders showed more microbial diversity than birds including the presence of opportunistic pathogens that could pose infection risk to the hummingbirds emphasizing the importance of proper feeder care. While in extreme cases infection might be lethal to hummingbirds, it is likely that low grade infections will impose a metabolic cost, increasing the challenge of energy-budget management.

22.1 STERN, DL*; DING, Y; BERROCAL, A; MORITA, T; LONGDEN, KD; STERN, David; Janelia Research Campus, UC Berkeley; *sternd@janelia.hhmi.org*

Natural Courtship Song Variation Caused by an Intronic Retroelement in an Ion Channel Gene

Animal species display enormous variation for innate behaviours, but little is known about how this diversity arose. Here, using an unbiased genetic approach, we map a courtship song difference between wild isolates of Drosophila simulans and Drosophila mauritiana to a 966 base pair region within the slowpoke (slo) locus, which encodes a calcium-activated potassium channel. Using the reciprocal hemizygosity test, we confirm that slo is the causal locus and resolve the causal mutation to the evolutionarily recent insertion of a retroelement in a slo intron within D. simulans. Targeted deletion of this retroelement reverts the song phenotype and alters slo splicing. Like many ion channel genes, slo is expressed widely in the nervous system and influences a variety of behaviours; slo-null males sing little song with severely disrupted features. By contrast, the natural variant of slo alters a specific component of courtship song, illustrating that regulatory evolution of a highly pleiotropic ion channel gene can cause modular changes in behaviour.

P1.243 STEVENS, LM*; MAYERL, CJ; HALL, G; RIVERA, G; VANCE, JT; PORTER, MM; BLOB, RW; Clemson University, Creighton University, College of Charleston; *lmsteve@clemson.edu*

Testing the effects of keels on stability and maneuverability in aquatic turtles

During swimming, animals can experience a variety of destabilizing forces, which can result in decreased energetic efficiency and locomotor performance. Many aquatic species exhibit external structural projections that, like the keels of boats, may increase their hydrodynamic stability. For example, juveniles of many aquatic turtle species possess small keels on the top of their shell (carapace), with some maintaining the keels into adulthood. To test if keels could provide similar stabilizing forces for turtles as they do for boats, we designed and affixed 3-D printed keels of various profiles to the carapace of a non-keeled turtle species, the painted turtle (*Chrysemys picta*). We used high-speed video to record turtles as they swam in a straight line following a prey stimulus. We then compared the performance between non-keeled swimming and swimming with keels of four size-shape configurations that span the range of those observed in nature. Our results did not indicate a substantial change in stability following the addition of any keel, though effects on maneuverability may be present. If keels do not provide locomotor benefits to swimming turtles, their presence and design may relate more strongly to other functional roles, such as inhibiting gape-limited predators and facilitating intraspecific or interindividual recognition.

65.2 STEWART, N.D*; MASTROMONACO, G.F; WARD, U.T.; BURNESS, G. ; Environmental & Life Sciences Graduate Program, Trent University, Reproductive Physiology, Toronto Zoo , Department of Biology, Trent University, Department of Biology, Trent University; *nathanstewart@trentu.ca*

The effect of island life on the morphology and stress physiology of white-footed mice

Island rodents are often larger, less aggressive and tend to live at higher and more stable population densities than their mainland counterparts. To test whether island life also affects the stress physiology of rodents, we collected hair and fecal samples from white-footed mice (*Peromyscus leucopus*) over two summers from islands (n = 6) and mainland locations (n=5) in the Thousand Islands region of the St. Lawrence River. This archipelago has been previously featured in studies of biogeographic theory. Hair provides an integrated biomarker of long-term (weeks-months) glucocorticoid levels, while feces provide a shorter-term (hours-days) measure of hormone metabolites, allowing for different time periods of stress to be compared. To determine if insular mouse populations in the Thousand Islands demonstrate traits typical of "island syndrome," we also used mark-recapture to measure population density, recorded morphological measurements and performed behavioural assays. Results will be discussed in relation to island size and degree of isolation from the mainland and population demographics.

S11.9 STEWART, Finlay J*; KINOSHITA, Michiyo; ARIKAWA, Kentaro; Sokendai, Hayama; *stewart@soken.ac.jp*

Colour and motion vision in a tetrachromatic butterfly

Visual motion is a particularly valuable cue for insects and other animals with poor spatial acuity, because optic flow provides a way to infer the three-dimensional structure of one's surroundings without relying on resolving fine detail. Using a virtual-reality system, we have demonstrated that flying swallowtail butterflies (*Papilio xuthus*) are attracted to targets that create the illusion, via motion parallax cues, of being nearby. However, we found no evidence that they quantitatively estimate the distance of targets. Like many Lepidoptera, *Papilio* has a rather complex retinal organisation compared to other insects. Its compound eye contains at least six distinct spectral classes of photoreceptors, and based on wavelength discrimination ability, its colour vision appears to be tetrachromatic. This spectral richness has interesting consequences for its motion detection system. By observing optomotor responses in tethered animals, we have found that - unlike most insects studied - *Papilio* can perceive motion using chromatic contrast in the absence of luminance contrast. Based on modelling results, we believe that this is the result of pooling signals from spectrally heterogeneous short visual fibres. Recently, we have been attempting to understand in detail the neural circuitry between photoreceptors and early visual interneurons. We have undertaken an ambitious project to elucidate the "connectome" of the *Papilio* lamina from serial block-face scanning electron microscopy (SBF-SEM) data. On the behavioural side, we have been investigating the nature of *Papilio*'s colour opponency system by characterising colour induction using a tetrachromatic display system. Preliminary results indicate that blue and green are mutually opponent, at least in females; this sensory system appears to be unexpectedly sexually dimorphic.

88.1 STEWART, JR*; ECAY, TW; KHAMBATY, M; East Tennessee State Univ.; *stewarjr@etsu.edu*

Functional Complexity in the Chorioallantoic Membrane of Corn Snakes, Pantherophis guttatus: Specializations for Calcium Uptake from the Eggshell

The eggshell is an important source of calcium for embryos of oviparous reptiles. Transport of calcium from the eggshell is a property of the chorioallantoic membrane. The chorionic epithelium faces the eggshell and is the primary tissue implicated in calcium mobilization and transport to the inner allantoic vascular system. Previous immunoblotting studies demonstrated an increase in expression of the calcium binding protein, calbindin-D_{28K}, and the enzyme, carbonic anhydrase II, in the chorioallantoic membrane of corn snake embryos coincident with calcium uptake from the eggshell. Calbindin-D_{28K} is a marker for calcium transport in squamate chorioallantoic membranes and carbonic anhydrase II is implicated in producing acidic environmental conditions conducive to solubilizing calcium from the inner aspect of the eggshell. We used immunohistochemistry to test the hypotheses that (1) cells expressing these two proteins are located in the chorionic epithelium and (2) the two proteins are expressed in different cells. Our results demonstrate that there are two cell types in the outer layer of the chorionic epithelium, one of which expresses calbindin-D_{28K} and the other carbonic anhydrase II. Differentiation of chorionic epithelial cells resulting in functional specialization of individual cells for either calcium mobilization or for calcium transport also occurs in embryonic chickens. The existence of a similar phenomenon in corn snakes suggests that these functional attributes are likely to be widespread among oviparous reptiles.

S10.5 STEWART, T.S.*; NOONAN, J.P; SANGER, T.J.; WAGNER, G.P.; Yale University, Loyola Univ. in Chicago; *tom.stewart@yale.edu*

The genetic basis of digit identity and evolution of the avian wing

Digits are an excellent model for studying the evolution and development of individuality in serial homologs. How digit identity is regulated or, indeed, whether digits have stable transcriptomic profiles that indicate discrete regulatory states, is unclear. While a number of genes have been identified as markers of digit identities, for example low expression of Hoxd11 seems to mark digit I of amniotes, comprehensive and comparative analyses of gene expression in digits are lacking. To discover the genetic basis of digit identity, we analyzed transcriptomes of developing limbs of American alligator (*Alligator mississipiensis*), green anole (*Anolis carolinensis*), and mouse (*Mus musculus*), chicken (*Gallus gallus*), and human (*Homo sapiens*). Limbs were sampled at comparable developmental stages, after digital condensation and once inter-digital webbing has begun reducing. RNA-Seq was performed on dissected digits and their associated, posterior inter-digital webbing, a known source of signals for digital identity. In situ hybridization was used to validate patterns of expression of identified candidate digit-identity genes. These analyses inform the variational independence and modularity of amniote digits, mechanistic hypotheses of limb morphogenesis, and human developmental malformations. Further, we identify stable transcriptomic profiles in chicken between the fore- and hindlimb. These analyses suggest a scenario for the evolution of the avian wing wherein the digits of chicken forelimb correspond to digits I, III, IV of other species.

109.6 STILLER, J*; WILSON, NG; ROUSE, GW; Scripps Institution of Oceanography, University of California, San Diego, Western Australian Museum, Perth, Australia; *jstiller@ucsd.edu*

The Covert Dragon: Phylogeography of the Seadragons (Syngnathidae) along the Temperate Australian coast

The southern coastline of Australia is home to a unique biota that has been exposed to complex changes throughout the glacial cycles. Glacial impacts on marine organisms of the region are less understood than in the northern hemisphere and detailed reconstructions of population histories were often hampered by the limited availability of genetic markers. Here, we investigate patterns of genetic structuring of two species of syngnathid fishes that are sympatric in parts of Australia's temperate coast. Both leafy seadragons (*Phycodurus eques*) and common seadragons (*Phyllopteryx taeniolatus*) are known for their remarkable camouflage mimicking seagrass and kelp. We used range-wide sampling of both species and sequenced ~1000 Ultraconserved Elements (UCEs) for >250 individuals. The genetic data is integrated with information on life history and geology to elucidate the phylogeographic structure and demographic history of each species and compare patterns between them. Both seadragons showed strong geographic structuring, consistent with their low dispersal potential. Considerable differences in genetic diversity existed regionally, some of which bearing signatures of recent changes in population size. A genetic break between populations of common seadragons in the southeastern part of the range coincides with the historical location of a land bridge connecting Tasmania to mainland Australia. Reopening of the seaway ~14,000 years ago resulted in opportunities for secondary contact and we found low levels of gene flow across the phylogeographic barrier. Overall, the high-throughput data provide a detailed picture of histories of both species and point towards complex factors influencing marine organisms in southern Australia.

126.6 STINSON, CM*; DEBAN, SM; University of South Florida; *cstinson@mail.usf.edu*

Functional trade-offs in salamander feeding performance due to morphological divergence

Salamanders use the hyobranchial apparatus to depress the floor of the mouth during aquatic suction feeding and to project the tongue from the mouth during terrestrial feeding. We hypothesized that morphological and functional compromises in the hyobranchial apparatus will yield decreased prey capture performance for semi-aquatic species that feed in both air and water when compared to fully aquatic species. We found the fully aquatic newt, *Paramesotriton labiatus*, has increased mineralization of the hyobranchial apparatus, as well as relatively more robust ceratobranchial I + II complexes and epibranchials, compared to semi-aquatic newts, and that this increased robustness is correlated with increased aquatic feeding performance. Maximum hyobranchial depression acceleration was found to be approximately three times greater than in semi-aquatic species, at 50 m/s/s. Particle image velocimetry revealed peak and average fluid velocities generated during suction feeding events (0.6 m/s and 0.2 m/s, respectively) were more than double those produced by all semi-aquatic species. These findings reveal that a more robust hyobranchial apparatus increases aquatic feeding performance in a fully aquatic newt and accompanies specialization for suction feeding.

66.6 STOCKER, MR*; ZHAO, LJ; NESBITT, SJ; WU, WC; LI, C; Virginia Tech, Zhejiang Museum of Natural History, Canadian Museum of Nature, Institute of Vertebrate Paleontology and Paleoanthropology; *stockerm@vt.edu*
A Short-snouted, Middle Triassic Phytosaur May Indicate Salt-Water Tolerance is Ancestral for Archosauria
Following the end-Permian extinction, terrestrial vertebrate diversity recovered by the Middle Triassic and was dominated by reptiles. However, these reptilian clades, including archosaurs and their closest relatives, are not commonly found until ~30 million years later in Late Triassic deposits despite time-calibrated phylogenetic analyses predicting an early Middle or even Early Triassic divergence for those clades. One of these groups from the Late Triassic, Phytosauria, is well known from a near-Pangean distribution, and this easily recognized clade bears an elongated rostrum with posteriorly retracted nares and numerous postcranial synapomorphies, particularly of the pectoral girdle, that are unique compared with all other contemporary reptiles. Here, we recognize the exquisitely preserved, nearly complete skeleton of *Diandongosuchus fuyuanensis* as the oldest and basalmost phytosaur. The Middle Triassic age and lack of the characteristically-elongated rostrum fill a critical morphological and temporal gap in phytosaur evolution, indicating that the postcranial modifications of phytosaurs occurred prior to rostral elongation. The cranial modifications that are present in *Diandongosuchus* suggest early modifications for prey acquisition, paralleling the trend that is later observed in crocodylomorph evolution. Based on the paleogeographic location and possible marine paleoenvironment of *Diandongosuchus*, we hypothesize salt-water tolerance as the mechanism for Phytosauria's pan-Tethyan distribution, adding to the growing body of evidence that the saltwater tolerance of birds and crocodylians was present in their most recent common ancestor and closest relatives.

90.1 STOEHR, AM*; WOJAN, EM; VANWANZEELE, DT; Butler University; *astoehr@butler.edu*
Temperature, Photoperiod and Nutrients Affect Phenotypically Plastic Wing Patterns in the Cabbage White Butterfly
Phenotypic plasticity is often an adaptation to varying environments but two inescapable features on environments and organisms may limit the adaptive significance of plasticity. First, environments vary in multiple and less-than-perfectly correlated ways meaning that an optimal response to one variable factor may result in less-than-optimal responses to another. Second, the integrated nature of organisms means that very often plasticity in one trait is not independent of plasticity of others; this, too, can limit optimal phenotypic plasticity. Our understanding of the limits of adaptive plasticity therefore depends upon studies that investigate multiple interacting environmental factors and the plasticity of multiple traits. The plastic wing pattern of the cabbage white butterfly serves as an ideal model for such an investigation because wing pattern elements vary in complex and in seasonally predictable ways. We examined the causes of wing pattern plasticity by experimentally manipulating temperature, photoperiod and dietary nutrients and find that all factors can, at least under some factor combinations, affect wing pattern elements. Furthermore, we find that in addition to these interactive effects, different wing pattern elements respond to environmental variation in different ways. Increased temperature increases the size of some wing pattern elements while decreasing the size of others. Photoperiodic variation also affected wing pattern, though to a lesser degree. Both temperature and photoperiod produced complex reactions norms for some wing pattern elements. Nutrient effects were relatively minor. Our results highlight the importance of including multiple environmental factors and multiple traits in studies of adaptive plasticity.

78.1 STOEHR, A*; ST. MARTIN, J; FOWLER, A; AALBERS, S; SEPULVEDA, C; BERNAL, D; Univ. of Massachusetts, Dartmouth, Univ. of Massachusetts, Amherst, Pfleger Institute of Environmental Research; *astoehr@umassd.edu*
Morphological and physiological mechanisms may control whole-body heat balance in deep-diving swordfish, Xiphias gladius.
Swordfish (*Xiphias gladius*) are unique among pelagic fish in their ability to undergo extensive dives characterized by rapid (minutes) and large (>18°C) changes in ambient temperature. Relative to other billfish, swordfish, possess anatomical traits [e.g., medial position of the aerobic red swimming muscles (RM), lateral blood vessels] that may allow for the retention of metabolic heat (regional endothermy) in the RM. However, to date there have been no studies detailing the presence of vascular specializations that may support RM endothermy and if swordfish are capable of altering rates of while body heat transfer during their dives. The objectives of this study were to (1) describe the vascular layout perfusing the RM, (2) measure water and body temperature in free-swimming swordfish, (3) and develop Newtonian and Fourier heat transfer models to elucidate potential physiological mechanisms governing RM endothermy or thermoregulation in free-swimming swordfish. Gross dissections and histological techniques revealed the presence of central retia as well as laterally positioned, closely opposed arteries and veins that may form rudimentary RM-associated heat exchanging retia. In addition, body temperature data and models suggest that manipulation of blood flow through retia of differential heat retention efficiency could describe the changes in whole-body heat transfer observed in free-swimming swordfish. Taken together, swordfish appear to possess anatomical specializations that permit physiological control of heat transfer, allowing swordfish to regularly exploit disparate thermal environments while maintaining a somewhat steady RM operating temperature.

P1.278 STORCH, JS*; HERNANDEZ, LP; The George Washington University, Washington, DC; *jdstorch@gwu.edu*
Network Analysis of Modularity Within the Cypriniform Trophic Apparatus: A Simulation Study
Cypriniform feeding morphology is characterized by three novel adaptations: kinethmoid-mediated premaxillary protrusion, the palatal organ, and mastication via occlusion of lower pharyngeal jaws against a chewing pad supported by the basioccipital. These three morphological solutions to the intake, discrimination, and processing of food by the trophic apparatus constrain each other inasmuch as they address sequential tasks that cumulatively manipulate a shared work product through a shared workspace within a continuity of function. Diverse morphological solutions in each of these three elements of the trophic apparatus across Cypriniformes provide a biological model with which we can investigate the evolution of complex systems. We present the results of a simulation study evaluating network analytic methods for the detection of modularity within a similar system. First we visualize morphological data from each element as a correlation matrix circumscribing the entire trophic apparatus. This matrix can be interpreted as a weighted adjacency matrix from which we extract a network topology. Community structure within the network topology is detected via analogy to an infinite range Potts spin-glass. We discuss the extent to which community structure can be interpreted as evidence of morphological integration and modularity, with particular attention to initial misspecification of the module. Abstraction of a biological model to a network representation allows us to use powerful analytic tools to interrogate the system.

P2.154 STORKS, L*; LEAL, M; University of Missouri - Columbia; *storksle@gmail.com*

A Field Based Approach to Study Behavioral Flexibility in Anolis sagrei

Behavioral flexibility allows individuals to modify their behavior in response to novel or shifting environmental conditions. Despite the potential role of behavioral flexibility in natural populations, very few studies have tested hypotheses about behavioral flexibility in the field. Here we have developed an experimental paradigm to evaluate behavioral flexibility under natural conditions in wild, free-living lizards (*Anolis sagrei*). We presented these lizards with a series of tasks evaluating associative, spatial, or reversal learning. Our results show that a subset of lizards can solve each task and that they make fewer errors as they proceed through each task. These findings open the door to further evaluate the role of cognition in fitness in wild animal populations.

P1.143 STOTHART, MR*; NEWMAN, AEM; University of Guelph; *mstothar@uoguelph.ca*

Uptown Squirrel: Tuning Life to an Urbanized World

A primary mechanism thought to enable vertebrate colonization of the nascent niches created in the wake of urbanization, is modification of a species' hypothalamic-pituitary-adrenal (HPA) stress axis. Understanding the ecology and physiology of synanthropic relationships is critical from both an environmental and human health perspective, as they are consequential for invasive species range expansion, and zoonotic, as well as sylvatic, pathogen transmission. We investigate the ecophysiological changes associated with urban environments using a using a combination of field, laboratory, and citizen science monitoring techniques, in an urban adapted mammalian model, the eastern grey squirrel (*Sciurus carolinensis*). Not only are eastern grey squirrels a major conservation concern as invasive species, and relevant from a disease perspective, but their ubiquity and visibility make them ideal candidates for novel citizen science initiatives. Particularly interesting however, is the existence of pelage colour polymorphs within grey squirrel populations which show evidence for 1) being adaptive on urban landscapes, and 2) physiological pleiotropy. In our urban-exurban investigations, we pair multi-temporal measures of HPA axis activity, immune function, and microbiome profiling with population level estimates of density and demography to characterize urban-exurban patterns in eastern grey squirrel physiology, and lay the foundation for future manipulative investigations.

32.8 STOVER, KK*; BRAINERD, EL; ROBERTS, TJ; Brown University; *kristin_stover@brown.edu*

Plodding poultry: Locomotor impacts of muscle mass distribution and altered center of mass in the turkey

A tetrapod's body shape determines the position of its center of mass (CoM), and both body shape and CoM can change with age, increases in body weight or gravidity. The domestic turkey has been artificially selected for increased body mass, and a past study reported an altered CoM position. In this study we seek to determine: (1) if muscle groups of the modern domestic turkey have experienced the same proportional increase in size compared to wild turkeys; (2) where the CoM is located in each strain; and (3) how CoM position affects locomotion. We dissected (n= 6 per strain) and grouped muscles by anatomical location (distal hindlimb, proximal hindlimb, trunk and forelimb) and calculated a ratio of muscle mass to total body mass. Only the trunk had a greater mass ratio in the domestic turkey (P= 0.004), driven solely by M. pectoralis (P=0.002), which is strongly selected for breast meat in the poultry industry. We measured the CoM position in 3D using a force plate and biplanar x-rays, and normalized with respect to pelvis length. The CoM was positioned 26% farther anterior to the acetabulum in the domestic relative to the wild turkeys (P=0.009). We assessed locomotion by measuring ground reaction forces as turkeys moved down a trackway with a force plate in the center. Fore-aft force (P=0.001) was lower at any given speed in the domestic turkeys compared to the wild turkeys. A reduction in fore-aft motion is also seen in elderly humans who walk with a more anterior CoM. The mediolateral forces in the domestic turkeys were higher for any given speed (P=0.001) much like obese humans. The change in turkey body shape has led to an anterior shift in the CoM position, and the resulting force pattern mirrors that of humans when mass distribution is altered.

52.3 STOWERS, AK*; LENTINK, D; Stanford University; *astowers@stanford.edu*

Wrist bones are important in pigeon wing morphing

Birds can morph their wings through a remarkable range of motion, enabling them to surpass insects, bats and aircraft in their ability to fly in varied environments. While bird wings bones are homologous to human forearm bones, the bird wing has a unique coupling between wrist and elbow motion allowing them to automate wing flexion and extension. Planar drawing parallel mechanisms have been used to model this motion in the past, but have not been corroborated with quantitative data. Here we measure how the skeleton of a pigeon (*Columba livia*) moves during wing morphing. With this data, we show that wing skeletal motion is actually highly nonplanar, highlighting the limitations of the drawing parallel mechanism. To elucidate the internal mechanism, we evaluate a series of hypothetical mechanism layouts including four-bars similar to the drawing parallels and those which include the wrist bones. We find mechanisms without any wrist bones to be anatomically infeasible, because they require the radius and ulna to cross to accurately match measured skeletal kinematics. Incorporating the wrist bones, we find better fits to our data as well as anatomically realistic mechanisms and recover a roughly parallel radius and ulna arrangement. This helps to demonstrate the importance of the wrist bones and coupling to avian flight.

P1.90 STRADER, MS*; MATZ, MV; The University of Texas at Austin; *stradermarie@gmail.com*

Double-stranded RNA knocks down expression of the target gene in coral larvae

Reef-building coral larvae expend their limited energy reserves producing costly GFP-like fluorescent proteins (FPs). The function of larval fluorescence is unclear but strongly correlates with dispersal related traits such as settlement and thermal tolerance. However, the causal link between FP expression and dispersal traits is not substantiated. We aimed to develop a method to knockdown red fluorescent protein production in larvae of *Acropora millepora* in order to identify the role of this gene on dispersal related traits in larvae, and more broadly, to develop a gene manipulation tool for reef-building corals to validate the roles of various candidate genes. This was approached with both a custom designed spice junction targeting vivo-morpholino and RNAi using 4 different transfection reagents complexed with double-stranded RNA for red FP. We found the most dramatic and significant reduction in larval redness using lipofectamine3000 and dsRNA, a result validated with qPCR. This is the first successful attempt at knocking down expression of a gene in a reef-building coral, which provides a key first step for investigating molecular mechanisms in coral larval physiology and development.

P1.172 STRAND, E*; HIZON, B; GLEASON, LU; DOWD, WW; Loyola Marymount Univ.; *estrand@lion.lmu.edu*

Plasticity of thermal tolerance and growth rates in juvenile mussels (Mytilus californianus)

To determine whether thermal tolerance in the mussel *Mytilus californianus* is genetically determined or whether juveniles adjust to their environment through phenotypic plasticity, we analyzed acute thermal stress tolerance and growth rates of common-garden acclimated and reciprocally transplanted mussel recruits. Juvenile mussels were collected from two low intertidal sites at Hopkins Marine Station in central California, wave-protected (warm) and wave-exposed (cool). One group was immediately exposed to an acute heat ramp to 35.8, 37.7, or 38.6°C in air to determine baseline heat tolerance. A second group was placed in a common garden for one month before exposure to the same acute heat ramps. The remaining mussels were reciprocally relocated to the origin field sites for one month and then subjected to heat stress. These treatments were repeated for two high intertidal sites from protected and exposed locations. Although not significant, there was a trend for greater baseline thermal tolerance in juveniles from the protected site. After one month, juveniles outplanted to the protected site exhibited higher survival following thermal stress, regardless of the origin site. Thermal tolerance and growth rate were inversely correlated; mussels from all origin sites were more thermally tolerant but grew more slowly at the protected location. Both origin site and outplant location significantly influenced growth rate. There was also a significant interaction between origin and outplant site - high-site juvenile mussels grew faster than low-site mussels when placed at the exposed site, but low-site mussels grew faster at the protected site. Our results imply substantial, environmentally driven plasticity in both thermal tolerance and growth rate among recent mussel recruits.

P1.276 STRAZNICKAS, BN*; JAECKLE, WB; Illinois Wesleyan University, Illinois Wesleyan University ; *bstrazni@iwu.edu*

Feeding on the Unseen: Ingestion and Assimilation of Bacteriophages by Brachionus plicatilis (Rotifera).

The rotifer, *Brachionus plicatilis*, ingests particulate foods ranging from 0.4 - 10 µm in size. Although clearance rates of small particles (< 1 µm) are low, bacteriophages (< 0.05 µm) are abundant in seawater (to 10^8/mL) and represent a potential food source for rotifers and other planktonic invertebrates. We incubated amictic females of *B. plicatilis* with dichlorotriazinylamino fluorescein (DTAF)-labeled bacteriophages (10^8/mL) or 900 pM DTAF in 0.2 µm-filtered seawater; the DTAF concentrations were equal in both treatments. After a 5-h incubation, the label in rotifers was detected using epi-illumination or confocal microscopy. The fluorescence of rotifers was greater in the DTAF-bacteriophage treatments than the unbound DTAF treatments; rotifers not exposed to the label revealed the lowest fluorescence. The distribution of the label within rotifers was similar for both experimental treatments. The greatest fluorescence was detected within the stomach and steadily decreased with increasing distance from this organ. In areas outside of the stomach, fluorescence was primarily diffuse and of lower intensity, but a small number of vesicles (4-5 µm) containing the label was detected. In the DTAF-bacteriophage treatments, stomach cells contained an abundance of fluorescent vesicles. The appearance of label in vesicles is consistent with earlier reports of pinocytotic uptake of materials by stomach cells. We hypothesize that bacteriophages and unbound DTAF entered the digestive system within an ingested flow of seawater. These findings indicate that bacteriophages in aquatic systems represent a previously unrecognized food source for planktonic invertebrates and their larvae.

P2.99 STROM, MK*; EBENSPERGER, LA; NOWAK, K; CALHOUN, K; TAIG-JOHNSTON, MR; HETTEÑA, A; ROMERO, LM; BAUER, CM; ABBOT, P; HAYES, LD; University of Tennessee-Chattanooga, Pontificia Universidad Católica de Chile, Tufts University, Pace University, Tufts University, North Dakota State University, Vanderbilt University; *mstrom90@gmail.com*

Are Ectoparasites or their Bacterial Communities Correlated with the Endocrine Stress Response in Degus (Octodon degus)?

The endocrine stress response allows vertebrates to appropriately react to stressful stimuli such as predator presence, low food availability, and social instability. By releasing glucocorticoids (GCs) into the bloodstream, the endocrine stress response essentially redirects energy from unnecessary physiological processes (e.g. reproduction, digestion) to those immediately necessary for survival (e.g. energy mobilization, heightened fight-or-flight response). Ectoparasitism may be one such stressor that elevates GC levels, yet the relationship between ectoparasite numbers and the endocrine stress response has not been well defined. We measured ectoparasite numbers and GC (cortisol) concentrations in two ecologically and geographically distinct populations of free-living degus (*Octodon degus*) in central Chile. Exotic fleas have been identified as the predominant ectoparasites in one population. Between populations, there may be variation in the ectoparasite species and their bacterial communities, potentially influencing cortisol levels. Thus, our aim is to explore the relationship between cortisol levels and ectoparasitism, including their associated bacterial communities, in two populations of degus.

P2.216 STROMSLAND, K*; ZIMMERMAN, LM; Millikin University, Millikin University ; *kstromsland@millikin.edu*
Effect of parasitic infection on natural antibodies in red-eared slider turtles
Comparison of reptilian and mammalian immune systems suggests that reptiles have a broader and less vigorous response that heavily relies on innate components of the immune system, whereas, mammals have a much stronger adaptive response to antigens. In order to compensate for their less robust response, it is believed that reptiles utilize natural antibodies that combat a variety of antigens. This study will help us to better understand the role and function of these natural antibodies in reptiles in response to parasites, as it is still unknown if natural antibodies are up-regulated in mucosal secretions and blood in response to antigens in this taxa. In order to do this, plasma and mucosal samples were collected from red-eared slider turtles captured from Rodney T. Miller Wetland in Decatur, IL to study antibody levels in comparison to parasite load, which was determined from fecal samples. Natural antibody levels to novel verse familiar antigens, and levels of natural antibodies in plasma verse mucosal samples were measured. Results demonstrate that there was no significant relationship between total antibody levels in plasma and parasite load; however, there was a trend for total Ig in mucosal samples. The data from this study will help to determine the effects of age and parasite exposure on the natural antibody response, and contribute to the understanding of reptilian immunity.

94.1 STROTHER, JA*; WU, ST; WONG, AM; NERN, A; ROGERS, EM; LE, JQ; RUBIN, GM; REISER, MB; Oregon State University, Janelia Research Campus, HHMI; *james.a.strother@gmail.com*
Origins of directional selectivity in the visual motion pathway of Drosophila
Visual motion perception is critical to many animal behaviors, and flies have emerged as a powerful model system for exploring this fundamental neural computation. Several recent studies have suggested that visual motion computation in Drosophila occurs in two parallel pathways, one that is selective to light increments (ON) and another that is selective to light decrements (OFF). To examine the emergence of directional selectivity in the ON pathway, we developed genetic driver lines for each of the major neuron types in the ON pathway. Using calcium imaging, we found that the output neuron type of the pathway (T4 cells) is directionally selective but its majors inputs (Mi1, Tm3, Mi4, and Mi9 cells) are not, indicating that directional selectivity emerges in T4 cells. By individually silencing each of the input neuron types, we identified which input neurons are necessary for T4 directional selectivity and ON motion behavioral responses. We then determined the sign of the connections between these neurons and T4 cells using neuronal photoactivation. Our results suggest a specific computational architecture for motion detection that is a hybrid of classic models for motion computation.

P3.165 STUPSKI, SD*; SCHILDER, RJ; Pennsylvania State University; *sqs6157@psu.edu*
Age-Related Functional Changes in the Flight Apparatus of the Hawkmoth, Manduca sexta
The ecological impact of an organism depends heavily on how it performs physiologically over a lifetime. Physiological performance may change drastically with age, but assessing the age of field caught individuals can be particularly difficult. On the other hand, while the effects of age on performance are more readily assessed in laboratory reared individuals, it is difficult to then assess their ecological relevance without corroboration in a natural population. Here we present how aging changes the performance of flight muscles in the hawkmoth, *M. sexta*. Specifically, we examined age-dependent changes in shivering thermogenesis, flight mill performance, and in situ muscle contractile performance in a laboratory colony. Additionally, we assess the potential of transcript levels of SCP1 as a method to age field caught *M. sexta* to validate our laboratory findings within natural populations.

25.5 STYNOSKI, JL*; WOMACK, M; TRAMA, FA; COLOMA, LA; HOKE, KL; Colorado State University, Fort Collins, CO, Centro de Capacitación en Conservación y Desarrollo Sostenible, Oxapampa, Perú, Centro Jambatu for Research and Conservation of Amphibians, Quito, Ecuador; *stynoski@gmail.com*
Repeated Evolution of Incomplete Ear Development in Acoustically Communicating Toads
Convergent evolution of novel traits can be adaptive, such as the loss of costly and superfluous sensory structures in cavefish and snakes. But, examples that apparently lack adaptive explanations also exist. For example, middle ear structures have disappeared among true toads (Bufonidae) at least 10 times, even though toads, like most anurans, primarily communicate with sound. To better understand these ear transitions despite the importance of acoustic communication, we have investigated whether there is consistency in the ways that earlessness develops in different lineages within the bufonid clade. We explored the behavior and developmental morphology of related pairs of eared and earless toad species using field observations and 3D reconstruction of developmental series resulting from captive breeding in Peru and Ecuador. We demonstrate that both eared and earless species call, although each lineage has distinct approaches to reproductive communication. We also show that earless species begin to grow middle ear structures like the columella and tympanic annulus, but this process is interrupted and differentiation of those structures does not follow the same trajectory as in eared species. Post-metamorphic regression of ear structures likely resulting from slowed development (heterochrony), which is common in bufonids, may have led to repeated ear loss and behavioral shifts in acoustic communication in toads.

10.2 SUKHUM, KV*; CARLSON, BA; Washington University in St. Louis; *kvsukhum@wustl.edu*

Extreme Enlargement of the Cerebellum is Associated with the Evolution of Electroreception

While there are clear differences in relative brain region size across vertebrates, it is unclear how these patterns evolved. The concerted hypothesis predicts brain region size has a predictable relationship with total brain size across species, as a consequence of developmental timing. The mosaic hypothesis predicts the sizes of brain regions can evolve independently due to selection acting on specific functions or behaviors. We addressed these hypotheses in mormyrids, a group of fishes that generate and detect weak electric fields. Mormyrids have a large brain and gigantocerebellum. However, no study has addressed how mosaic and concerted changes have contributed to the evolution of mormyrid brains. We did micro-computed tomography scans of brains of 6 mormyrid and 3 outgroup species. We measured the volumes of 8 brain regions. Within clades, the size of each brain region scaled with brain size, as predicted by concerted evolution. However, we also found evidence for mosaic evolution, with mormyrids having a disproportionately large cerebellum compared to outgroups. Further, the concerted hypothesis predicts the cerebellum and telencephalon should show disproportionately large growth as brain size increases, since they are generated latest in mammals. However, we found the torus semicircularus showed the greatest growth with increasing brain size, suggesting either the sequence of neurogenesis is different from mammals, or it is not responsible for the differential scaling of brain regions. Finally, the outgroup species *Xenomystus nigri* is electroreceptive but does not actively generate electric fields. Like mormyrids, its cerebellum was disproportionately large compared to other outgroup species. Thus, our results suggest the evolution of electroreception has driven mosaic expansion of the cerebellum.

66.8 SUMMERS, AP*; CONWAY, KW; BUSER, TJ; HAYES, MM; PFEIFFENBERGER, JA; SUMMERS, Adam; University of Washington; *fishguy@uw.edu*

CT scanning all the fishes...techniques and a progress report

Computed tomography scanning with x-rays is an effective method for visualizing radiodense skeletal tissues. With the addition of contrast techniques, iodine or phosphotungstic acid for example, it is also capable of revealing soft tissue anatomy. CT scanning has been expensive and the reconstructions of specimens a time consuming process that required expensive software. We report on simple techniques for scanning large numbers of specimens at the same time. The data are then digitally dissected into single specimen scans. An important question to consider when bulk scanning is resolution - it will certainly be less than can be achieved scanning a single specimen. We propose a policy of scanning fishes at a resolution that allows morphometric measurements at higher resolution than traditional 2-D techniques (i.e. calipers, ocular micrometers). The throughput that is possible with a single CT scanner and a single person doing reconstructions is demonstrated at 40 specimens per day. We expect it is possible for a single person to scan 50 specimens a day of similarly sized fishes. We are engaged in scanning a specimen of every species of fish. Each species will be scanned at a resolution sufficient for many purposes. Slice data, STL files, PLY files and JPGs of volume and surface renderings are being made available immediately through an open access model. We have scanned over 600 species. Uploading the data to the web remains a bottleneck. The processes we have developed for rapidly scanning, tracking and returning specimens are also available open access as living documents.

P3.228 SUMNER, B; Stony Brook University; *bonniesumner1@gmail.com*

The evolution of the cost of walking and running in amniotes

How an animal moves, and the energy required for that movement, has a profound effect on the evolutionary success of a given species. This study aimed to determine the evolution of cost of transport, the energy required to move a kilogram one meter, across amniotes. This study used comparative phylogenetic methods to demonstrate the complex evolutionary pattern of cost of transport among amniotes. I compiled previously published data on the net metabolic cost of both walking and running separately after subtracting the resting or standing cost. I then used phylogenetic adjusted statistics and Ornstein-Uhlenbeck modeling to determine substantial rate shifts along branches of the phylogenetic tree. Non-paleognathous birds have undergone a large increase in cost of transport, which suggests that the evolution of flight prevents terrestrial locomotion from being at its adaptive optimum. Domesticated camels and donkeys have undergone a substantial decrease in cost of transport from their closest living relatives. Previous research has suggested that their exceptionally low cost of transport is an adapative response to harsh environments. The results of this study are in line with this hypothesis, although further research is needed to determine whether it is a result of artificial selection, environment, or both. Turtles have a very low cost of transport, but the magnitude of the shift of cost of transport cannot be determined at this time due to the 230-million-year divergence from archosaurs and sparse sampling. Wallabies are the only taxon that have undergone directional selection on the cost of transport for running, resulting in an exceptionally efficient gait. It is possible that the lack of selection in other lineages may indicate that there is relaxed selection on cost of transport in running in comparison to walking.

82.3 SUMNER-ROONEY, LH*; RAHMAN, I; SIGWART, JD; ULLRICH-LÜTER, E; Museum für Naturkunde, Berlin, Oxford University Museum of Natural History, Queen's University Belfast; *lsumnerrooney01@qub.ac.uk*

Eyes in their Stars? Photoreceptor Anatomy and Visual behaviour in Ophiocoma

Vision and photoreception in echinoderms have perplexed researchers for more than a century. In recent years, new experiments and novel techniques have revealed not only large numbers of opsin genes and photoreceptors, but the presence of image formation in sea stars and urchins. *Ophiocoma wendtii* is a common Caribbean brittle star that undergoes dramatic photoresponsive colour changes and exhibits strong negative phototaxis. It has become an iconic species in vision research, speculatively possessing a unique whole-body compound eye. Hemispherical crystalline calcite structures on the aboral surface are thought to focus incoming light onto sensory nerve bundles beneath, which could be integrated to allow spatial resolution. However, no photoreceptor cells have been identified to date, and behavioural studies in *O. wendtii* have been limited, despite widespread references to its visual ability. We present the first definitive evidence of an extensive extraocular photoreceptor network, and the first empirical support for low resolution vision, in *O. wendtii*. Histology, immunolabelling and synchrotron tomography demonstrated that thousands of putative photoreceptors are likely responsible for *O. wendtii*'s photosensitivity. Target-seeking experiments showed that animals were indeed able to detect large shapes from a distance and move towards them, suggesting they could be capable of integrating activity from the many photoreceptors to contribute to an elementary form of spatial vision. Light-dark choice experiments under manipulated light spectra demonstrate that light evasion behaviour in *O. wendtii* is likely elicited by blue wavelengths. Furthermore, it appears that a similarly extensive whole-body photoreceptor system could be present in two more congeneric species.

P3.246 SUN, S*; WERNING, S; Des Moines Univ; *sarah.werning@dmu.edu*

Growth and scaling in male and female Spectacled Caiman (Caiman crocodilus) from Venezuela

Femoral measurements are often used to estimate the body size of extant crocodylians and their extinct ancestors when snout-vent length (SVL) or mass cannot be measured directly. These relationships are often based on osteological specimens that lack sex data and do not account for sex. However, sex is an important determinant of crocodylian body size; most extant species are sexually size dimorphic, usually with larger males. Size differences may result from differences in scaling trajectory, growth rate, or growth duration; if males and females differ significantly in their ontogenetic scaling trajectories, the accuracy of current size predictive models is questionable. We measured 224 femora from a single population of wild Spectacled caiman ranging in size from near-hatchlings to large adults. All specimens have associated sex, mass, SVL, and total length (TL) data. We used ordinary least squares linear regression to describe the relationships among several femoral measurements, SVL, TL, and mass. To test whether caimans show sex differences in proportions or scaling trajectories unrelated to overall body size, we performed an analysis of covariance for each regression. Male and female scaling relationships cannot be statistically distinguished from each other or from pooled-sex data, suggesting that femoral estimates of crocodylian body size do not need to account for sex. We also constructed skeletochronological growth curves using a subset of 66 individuals. Males grow much faster than females until sexual maturity, but afterwards grow similarly. Although femoral proportions are not sexually dimorphic, differences in growth rate suggest that size in combination with relative morphological maturity (e.g. presence of femoral muscle scars) may be useful to estimate sex of skeletal specimens.

40.5 SUNDIN, J*; CLARK, TD; AMCOFF, M; MATEOS-GONZáLEZ, F; RABY, GD; BINNING, SA; ROCHE, DG; SPEERS-ROESCH, B; JUTFELT, F; Uppsala Univ., Uppsala, Univ. of Tasmania & CSIRO Agriculture and Food, Hobart, Univ. of Texas, Austin, Univ. of Texas, Austin, Univ. of Windsor, Windsor, Univ. of Neuchâtel, Neuchâtel, Univ. of New Brunswick, Saint John, Norwegian Univ. of Science and Technology, Trondheim; *josefin.sundin@neuro.uu.se*

Temperate and Coral Reef Fishes Show Negligible Physiological and Behavioral Responses to Elevated CO_2

Much of the anthropogenically-released carbon dioxide (CO_2) dissolves in the ocean, causing ocean acidification (OA). CO_2 is predicted to increase in the ocean from current levels of ~400 µatm to end-of-century levels of ~1000 µatm. Exposure to predicted end-of-century CO_2 levels has been reported to affect the physiology and behavior of fishes, which could have detrimental consequences for population viability in the future. However, a growing number of studies report no physiological or behavioral changes, suggesting species- or experiment-specific effects and a far from complete understanding of the true impacts of OA. We investigated the possible effect of both short- and long-term exposure to ~1000 µatm CO_2 on fish physiology and behavior, using in total ten different species of wild-caught temperate fishes, and wild-caught as well as laboratory-raised coral reef fishes. We filmed all trials and used automated methods to ensure objectivity and transparency. We did not detect any significant impairments in the physiology or behavior of any of the species, revealing that all species were resilient to CO_2 exposure. Further, we found no evidence to suggest a role of OA in the interference of $GABA_A$ neurotransmitter function. Our findings highlight the need for independent replication before we can reach a consensus on the ecological and physiological effects of OA on fishes.

28.2 SUTHERLAND, V; PHIPPEN, B; REITZEL, AM*; Univ. North Carolina, Charlotte; *areitze2@uncc.edu*

Ecological and Developmental Effects of the Microbiome Associated with the Sea Anemone Nematostella vectensis

Every animal on Earth is associated with a diverse community of bacteria (their microbiome). Recent research has suggested that microbiomes are important and in some cases essential partners for the development, health, and longevity of their animal host. Despite a few well documented examples of the benefits to animals from the associated bacteria, the functions and potential importance of the microbiome for most species, particularly marine organisms, remain little studied. Here we will present research aimed to characterize some functional interactions of the microbiome in the development and abiotic stress tolerance for an estuarine sea anemone, *Nematostella vectensis*. Using a combination of antibiotic treatments and single-bacteria inoculations, our results show significant effects of bacteria on the timing of development as well as the tolerance to two abiotic stressors, temperature and salinity. Furthermore, exposing anemones to live cells or cell-free supernatant from 24 species of common estuarine bacteria (e.g., *Vibrio*) and known human pathogens (e.g., *Pseudomonas*) revealed substantial variation in how bacteria influence the life cycle of this cnidarian. We will place these results in the context of previous data on the variation in the microbial community of *Nematostella* over development and in different populations to connect microbial variation with cnidarian ecology. Our continued research will further determine the role for bacteria in this species to identify how microbes may facilitate, or limit, the health and survival of its host in the dynamic natural environment.

S5.11 SUZUKI, T.A.*; PHIFER-RIXEY, M.; FERRIS, K.G.; CHAVEZ, A.; MARTINS, F.M.; NACHMAN, M.W.; Univ. of California, Berkeley, Monmouth Univ., Univ. California, Davis, Ohio State Univ. , Australian National Univ.; *taichis@berkeley.edu*

Gut microbiome and Bergmann's rule in natural populations of house mice.

Bergmann's rule is the observation that animals at more extreme latitudes have a larger body mass compared to animals at lower latitudes, presumably reflecting an adaptation to colder climates. Recent advances in microbial ecology have demonstrated that the obesity-associated microbiome can provide greater energy extraction from a diet by breaking down indigestible plant polysaccharides and promoting fat storage. To what extent gut microbes play a role in adaptive body size variation remains largely unexplored. Here, we combined field and laboratory based approaches (1) to understand the environmental and genetic factors associated with the gut microbial variation, and (2) to test the function of gut microbiome in relation to host body size variation. We characterized the gut microbial composition of 17 natural populations of house mice (*Mus musculus*) across North and South America using 16S amplicon sequencing. The overall microbial variation was correlated with climatic variables, body size, diet (carbon and nitrogen stable isotopes), and host genetic distance (exome capture data). We identified host genomic regions associated with microbial measurements using Latent Factor Mixed Models. We show a positive correlation between obesity-associated microbiome (i.e. greater ratio of Firmicutes and Bacteroidetes) and latitude, a consistent pattern with humans. In addition, we found microbial diversity measurements positively correlate with body size, both in wild and lab populations. Fecal transplant experiments are being conducted to understand the causal role of gut microbes in Bergmann's rule, a fundamental pattern in evolutionary biology.

S1.2 SWADDLE, John P; College of William and Mary; *jpswad@wm.edu*

Animal Communication and Species Interactions in a Changing World: Consequences of noise pollution

Humans are changing the environment at unprecedented rates, which can put intense ecological and evolutionary pressures on wildlife. One of the most prevalent yet relatively understudied forms of anthropogenic change is noise pollution. Here I will give an overview of the effects of noise pollution on birds, focusing on our group's studies of zebra finches' and eastern bluebirds' communication strategies in the face of noisy conditions. These studies indicate that individual birds show substantial flexibility in their vocal strategies, but that withstanding noisy environmental conditions carries developmental and fitness costs. As noise imposes costs, I will also discuss our emerging line of research whereby we are deliberately deploying spatially-controlled "nets" of masking sound, which make it hard for birds to hear each other or predators, to displace nuisance birds from sites of economic importance—such as farms and airports, where birds can cause tremendous damages. Further I will discuss how we can use targeted sound to reduce the risk of birds' collisions with buildings and wind turbines. Hence, though uncontrolled noise pollution is damaging to many bird species, spatially controlled noise can help mitigate and limit conflict between birds and human development.

109.3 SWAFFORD, AJ*; OAKLEY, TH; Univ. of California, Santa Barbara; *andrew.swafford@lifesci.ucsb.edu*

The Speed of Light: Duplication rates in opsin family evolution.

Changes in rates of gene duplication influence the structure of genomes and affect the available source material for evolutionary novelties. One driver of duplication rates could be changes in the function of genes. However, there are only a few cases where higher duplication rates correlate with shifts in gene function. Here, we show that rates of duplication in the opsin gene family are related to gene function. To quantify rates of opsin duplication, we first needed a time tree for the gene family. We estimate that a lysine residue that may be diagnostic of opsins evolved 808-784 MY ago and most visual opsins originated 705-654 MY ago. Using the time tree and a binary state speciation and extinction (BiSSE) model, we estimated the birth and death (=duplication and loss) rates for opsins associated with both visual or non-visual character states. We find duplication rates of visual opsin clades significantly differ from non-visual clades ($P<0.001$). Our results identify crucial events for the evolution of animal vision on an absolute timeline, and demonstrate a case where duplication rates in gene families correlate with the evolution of new functions.

PLEN.1 SWALLA, B.J.; University of Washington at Seattle; *bjswalla@u.washington.edu*

Follow the Yellow Brick Road: An Odyssey from Myoplasm to Marine Biology to Genomics

Follow the Yellow Brick Road, from an undergraduate at the University of Iowa with a keen interest in eggs to the Director of a Marine Lab, helping to network the many Pacific Marine Labs into a comprehensive Pacific Ocean Observatory. Tracing my path reminds me of the Wizard of Oz, with a yellow brick road that holds many surprises, plot twists and turns, featuring a cast of interesting characters and never really reaching a conclusion. It starts in the Midwest, in Iowa, and ends for now in the Pacific Northwest, on San Juan Island, at Friday Harbor Labs. The constant throughout my scientific career has been a love of invertebrate eggs and embryos, which has blossomed into studying genomics and marine biodiversity. My lab works on evolution and development, studying both closely related species with radically different body plans and very divergent taxa, in order to understand the evolution of body plans at both genetic and morphological levels. This research has taken me to some amazing places and left me with some incredible friends, mentors and colleagues. I'll conclude my lecture with some thoughts about the future of Marine Labs and how they continue to inspire and educate people about science with experiential learning. I'll also talk about the importance of ocean monitoring, networks and citizen science in an increasingly complex human society.

P2.35 SWANDA, RV; VOSS, MA*; Syracuse University, Syracuse, NY; *rs2363@cornell.edu*

The Effects of Ambient Light on the Disruption of Endocrine and Neurobiological Mechanisms that Control Glucose Homeostasis.

For much of our species' history, humans have attempted to light the night skies in order to increase productivity. Unfortunately, artificial light at night is one of several environmental factors that can disrupt natural circadian rhythms. Circadian clocks influence metabolism through diverse mechanisms, including gene expression, cell division, and endocrine regulation. We are interested in the effects of light at night (LAN) on neonatal metabolism and growth. We have used free-living Barn Swallows as a model system to track the metabolic effects of altered circadian rhythm due to LAN during neonatal development. Control nests experienced a natural light:dark cycle from incubation to fledge (approximately 25 days), while treatment nests experienced a 24 hour light cycle (480 nm wavelength LED light positioned approximately 15cm above the eggs). Post hatch measurements were taken every other day on the length of the head, bill, and wingspan (mm) to determine the effect of altered circadian rhythm on bone growth and keratin production. Weight, fat scores, and blood glucose levels were also measured. Birds from the treatment nests had lower blood glucose levels, abnormal growth patterns, and evidence of disrupted protein production. Birds normally maintain high blood glucose levels as an adaptation for flight. Blood glucose levels in our light treatment birds were lower than those of the controls, a sign of stress. Our results suggest that LAN contributes to metabolic dysfunction in a free living wild bird species, and thus adds to a body of evidence suggesting the man-made environment has the capacity to alter the metabolic health of both humans and wildlife.

39.4 SWANSON, EM*; SNELL-ROOD, EC; University of Minnesota - Twin Cities; *eliswanson@gmail.com*

The evolution of hormonal control of life histories: a case study with juvenile hormone

Hormones regulate phenotypic development in response to genetic and environmental variation. These molecular signals thus represent the underlying targets of phenotypic selection. Our understanding of the genetic basis of these signals, as well as their functional roles, is constantly improving. But how do molecular signals evolve in concert with the phenotypes they regulate? Our knowledge here is rudimentary. For example, although we know that hormonal pleiotropy generates correlations among phenotypic traits and plays an important role in phenotypic integration, we don't fully understand the role of pleiotropy in evolution. We set out here to test the hypothesis that phenotypic responses of life-history traits to hormone variation evolve in a conservative fashion. We predict that variation in these responses results from tissue-specific expression of the same downstream effectors, even across large taxonomic groups. We measured variation in life-history traits and trade-offs responding to the same hormone manipulation in different butterfly species. We then used gene expression data in different tissues to better understand the molecular basis of the developmental mechanisms underlying the measured phenotypic variation in these species. Our results suggest in part that juvenile hormone affects some traits similarly in nearly every species we measured, but the strength and even direction of effect on other traits vary among species. We will connect these and other results from our experiments on life-history variation to our gene expression data on multiple species and tissues. In addition to identifying the molecular developmental basis of the effects of juvenile hormone on life-history variation among butterflies, we will test our hypothesis by investigating the consistency of evolutionary responses in specific downstream molecular signals.

132.6 SWITZER, C.M.*; COMBES, S.A.; Harvard Univ., Univ. of California, Davis; *callin.switzer@gmail.com*

The neonicotinoid pesticide, imidacloprid, affects Bombus impatiens (bumblebee) sonication behavior when consumed at doses below the LD50

We investigated changes in sonication (or buzz-pollination) behavior of *Bombus impatiens* bumblebees, after consumption of the neonicotinoid pesticide, imidacloprid. We measured sonication frequency, sonication length, and flight (wing beat) frequency of marked bees collecting pollen from *Solanum lycopsersicum* (tomato), and then randomly assigned bees to consume 0, 0.0515, 0.515, or 5.15 ng of imidacloprid. We recorded the number of bees in each treatment group that resumed sonication behavior after consuming imidacloprid, and re-measured sonication and flight behavior for these bees. We did not find evidence that consuming 0.0515 ng imidacloprid affected the sonication length, sonication frequency, or flight frequency for bees that sonicated after consuming imidacloprid; we were unable to test changes in these variables for bees that consumed 0.515 or 5.15 ng because we did not observe enough of these bees sonicating after treatment. We performed Cox proportional hazard regression to determine whether consuming imidacloprid affected the probability of engaging in further sonication behavior on *S. lycopersicum* and found that bumblebees who consumed 0.515 or 5.15 ng of imidacloprid were significantly less likely to sonicate after treatment than bees who consumed no imidacloprid. At the end of the experiment, we classified bees as dead or alive; our data suggest a trend of increasing mortality with higher doses of imidacloprid. Our results show that even modest doses of imidacloprid can significantly affect the likelihood of bumblebees engaging in sonication, a behavior critical for the pollination of a variety of crops and other plants.

72.3 TAFF, CC*; VITOUSEK, MN; Cornell University; *cct63@cornell.edu*

Individual variation in behavior, physiology, and fitness in response to experimentally induced acute stress in wild tree swallows.

Conceptual models suggest that the cost of mounting repeated physiological responses to stressors will depend on both the severity and duration of acute stressors, yet few studies manipulate stressors in a graduated fashion. We studied individual variation in both the response to—and downstream consequences of—repeated exposure to brief spikes in corticosterone. We experimentally induced acute corticosterone spikes on either three or six consecutive days in incubating tree swallows and compared the effects of these treatments to two control groups. Our manipulations were accomplished non-invasively by applying corticosterone dissolved in DMSO gel to an artificial egg so that each dose was absorbed across the female's brood patch without the need for capture on treatment days. Females in all groups were captured once before treatment and twice post treatment to collect measurements and blood samples. At our capture points, we measured both baseline and stress induced corticosterone concentration as well as the efficacy of negative feedback following injection with dexamethasone. Additionally, we measured glucose mobilization from baseline to 30 minutes post capture and two markers of oxidative metabolism pre- and post treatments. Finally, all nests were equipped with RFID readers and each adult was marked with a PIT tag to record continuous information on parental incubation and provisioning rates before, during, and after treatments. We discuss both the mean effects of our graduated series of acute stressors and the role of individual variation in pre-treatment physiology in determining the downstream behavioral and physiological consequences of repeated exposures to acute and unpredictable physiological stressors.

P1.221 TAFT, NK*; TAFT, BN; DIAMOND, KM; SCHOENFUSS, HL; BLOB, RW; University of Wisconsin Parkside, Carthage College, Clemson University, St. Cloud State University, Clemson University; *taft@uwp.edu*

Mechanical specializations of the fin rays in waterfall-climbing gobiid fishes

Fishes in the gobiid lineage have evolved a specialized pelvic suction disc from the fusion and modification of the pelvic fins. The stream habitats of Hawai'i host a number of gobiid species, some of which have evolved the ability to climb waterfalls. In this study, we tested whether the pelvic fin rays of climbing species exhibit morphological or mechanical specializations compared with fin rays associated with non-climbing structures (caudal rays), or rays of non-climbing species. We compared pelvic and caudal rays from four species: *Sicyopterus stimpsoni*, an inching climber; *Awaous guamensis*, a powerburst climber; *Stenogobius hawaiiensis*, a non-climbing species with a pelvic disc, and *Eleotris sandwicensis*, a non-climber in the outgroup to gobies, with unfused pelvic fins. We used three-point bending to measure the flexural stiffness (EI) of pelvic and caudal fin rays, and used mixed linear models to examine differences in EI between climbing and non-climbing species, and between pelvic vs. caudal fin rays. The pelvic discs of the two climbing species are relatively smaller and more rounded than those of non-climbers, with highly branched fin rays. In our mechanical tests, we found that the flexural stiffness of pelvic fin rays from climbing species is significantly lower than in pelvic rays from non-climbing species, resulting in more flexible pelvic rays in climbers. The caudal fin rays are more stiff than the pelvic rays for all species, but the those of the climbing species are more flexible than those of the non-climbers. These comparisons indicate that structural adaptations contributing to higher flexibility in the fins may have facilitated the evolution of climbing performance in gobies.

145.5 TAFT, NK; University of Wisconsin-Parkside; *taft@uwp.edu*
Combatting Stereotype Threat in Introduction to Organismal Biology
Stereotype threat can be defined as distress associated with the prospect of confirming a negative stereotype about a group to which one belongs. Stereotype threat is associated with lower performance in science courses in women, underrepresented minority (URM) groups and first-generation college students. At UW Parkside, 53% of students are first generation and 30% are from URM groups. Our population is potentially at risk for stereotype threat in large science courses like introductory biology. I performed a controlled experiment implementing a one-time, brief values-affirmation writing intervention in the first week of a large introductory biology course. Despite its simplicity, this values-affirmation writing exercise has been shown to positively affect performance in first-generation and underrepresented minority groups. In this study, students who had the opportunity to affirm their values in writing in the first week of classes showed a 7% better performance on their average exam scores for the semester. In contrast to previous work all students benefitted, on average, from participating in the values affirmation compared to control group. This includes males and females, continuing and first-generation students, URM students and non-URM students. Although an achievement gap between URM and non-URM students persists, URM students participating in the intervention had an 8.5% increase in exam performance overall versus those in the control group. In contrast, there was no significant gap between first generation and continuing-generation students. This suggests that stereotype threat can work differently at different college environments, and more work needs to be done to explore this issue on different types of campuses.

P3.164 TAHIR, U*; NISHIKAWA, KC; Northern Arizona Univerisity; *ut5@nau.edu*
Force-velocity relationship of muscle varies during isovelocity, after-loaded isotonic and cyclical muscle contractions.
Intrinsic properties enable muscles to change force output in response to changes in load, length and velocity instantaneously, without feedback from the nervous system. Muscle force increases with active stretching and decreases with active shortening. The force velocity relationship describes how muscle force decreases with increasing shortening velocity, up to maximum shortening velocity, Vmax. The force-velocity relationship is typically attributed to the attachment and detachment kinetics of the cross bridges, but is often only studied in supra-maximally activated muscles in after-loaded isotonic contractions. After-loaded isotonic contractions remove the contribution of the series elastic elements, theoretically permitting the study of active cross bridges alone. This relationship can also be obtained from experiments in which muscles experience isovelocity or cyclical length changes that include series and parallel muscle elasticity. The goal of the present study was to investigate how the force velocity relationship of muscles varies with the changes in strain trajectories. Soleus muscles from mice were isolated and attached to a force lever to measure muscle force and length. Muscles were stretched and shortened under isovelocity, isotonic or cyclical strain trajectories over a range of lengths from ±2% to ±10% of optimum muscle length (L0). We fit all force-velocity curves in the shortening domain to a modified Hill equation. Data suggest that maximum shortening velocity and power are highest in maximally stimulated muscles undergoing cyclical contractions. Afterloaded isotonic contractions showed an intermediate maximum power. Predicted Vmax was similar in under isotonic and isovelocity contractions. This study demonstrates that the force-velocity relationship changes depending on strain trajectories.

73.6 TALAL, S*; AYALI, A; GEFEN, E; Tel Aviv University, Israel, University of Haifa - Oranim, Tivon, Israel; *stav.talal@gmail.com*
Discontinuous Gas Exchange does not Contribute to Evolved Resistance to Desiccation in Laboratory-Selected Migratory Locusts
The hygric hypothesis for the evolution of the discontinuous gas exchange (DGE) pattern in insects posits that DGE serves primarily to reduce respiratory water loss. In this study we directly tested predictions of the hygric hypothesis by using, for the first time, an experimental evolution approach. We compared populations of the migratory locust (*Locusta migratoria*) that underwent ten consecutive generations of selection for desiccation-resistance, with corresponding control populations. Response to selection was reflected in a 36% longer survival time of the experimental populations compared to controls, at 30° C, with no access to fresh food (8.3±0.4d and 6.1±0.3d, respectively). In contrast with one prediction of the hygric hypothesis, DGE prevalence did not differ between selected and control populations (circa. 75% in both groups). We recorded significantly lower evaporative water loss rates (EWL) and higher body water content in the hydrated selected populations. Selected locusts exhibited significantly longer DGE cycles than controls (longer interburst but not burst durations). However, in contrast with predictions of the hygric hypothesis, these evolved changes in DGE properties were not associated with reduced rates of respiratory water loss in the selected locusts. Hence, our data suggest that longer cycle and interburst durations are a consequence of an evolved increased ability to store water, and thus buffer accumulated CO_2, rather than an adaptive response to desiccation stress. We conclude that the DGE pattern is unlikely to be an evolutionary response to dehydration challenge in locusts.

P2.243 TALAL, S*; GEFEN, E; AYALI, A; Tel Aviv University, Israel, University of Haifa - Oranim, Tivon, Israel; *stav.talal@gmail.com*
Electromyogram of Locust Spiracle and Abdominal Muscles During Discontinuous Gas Exchange Cycles
Discontinuous gas exchange (DGE) is the best studied among gas exchange patterns in insects. DGE cycles comprise three phases, which are defined by spiracular state: close, flutter and open, although spiracle status has rarely been monitored directly. Instead, it is often assumed based on recorded respiratory gas traces. Furthermore, previous studies on the role of spiracle control in gas exchange patterns have focused almost exclusively on lepidopteran pupa during diapause. In this study we directly monitored muscular activity associated with DGE in adult locusts. We carried out electromyogram (EMG) recordings from the closer muscle of the second thoracic spiracle and from abdominal ventilation muscles simultaneously with recording of CO_2 emission from a fully intact animal during DGE. We found that during the open phase, when CO_2 emission rate is the highest, the spiracles open and close rapidly. The spiracle activity occurred in-phase with abdomen ventilation and in opposite phase to the last abdominal spiracle, thus facilitating a unidirectional flow of air through the grasshopper. Moreover, the spiracle instantaneous frequency (the frequency of spiracle transition from open to close state and vice versa) was correlated with the CO_2 emission rate. We also found a strong correlation between the number of spiracle openings and the amount of CO_2 that accumulates during the DGE cycle interburst (the close and flutter phases). We show that during the flutter phase abdominal ventilation is coupled with thoracic spiracle closure, suggesting gas exchange through the abdominal spiracles only.

23.3 TAMVACAKIS, A N*; BOYKIN, J; KATZ, P S ; Georgia State University; *tamvacakis@gmail.com*
Differential expression of serotonin receptor genes in homologous neurons underlies species-typical swimming behaviors in Nudipleura sea slugs
Neuromodulatory receptors, such as serotonin receptors (5HTRs), change neuronal and synaptic properties, thereby altering behavioral outputs of neural circuits. In the sea slug *Tritonia diomedea* (Mollusca, Gastropoda, Nudibranchia), 5HT plays a role in activating rhythmic dorsal-ventral (DV) swimming by enhancing the strength of synapses made by the C2 neuron, which is part of the swim neural circuit. The identity of 5HTRs expressed by C2 homologues was previously unknown. *Hermissenda crassicornis*, another nudibranch, has C2 and serotonergic neuron homologues, but does not produce a DV swim. Furthermore, 5HT does not modulate *Hermissenda* C2 synaptic strength. In contrast, *Pleurobranchaea californica*, from the sister clade Pleurobranchomorpha swims with DV flexions in an analogous manner to *Tritonia* and 5HT enhances synaptic strength of the *Pleurobranchaea* C2 homolog. Phylogenetic analyses indicate that *Tritonia* and *Pleurobranchaea* evolved swimming independently. We hypothesized that 5HTR gene expression underlies species-typical behaviors. We predicted that 5HTR subtype expression would be similar in DV swimming species and different from non-DV swimming species. We used two approaches to examine 5HTR expression in C2 homologues: single-cell transcriptomics and single-cell quantitative PCR (qPCR). We found that receptor subtype 5HT7 was expressed only in C2 homologues of DV swimmers. Thus, differential expression of 5HTRs in C2 homologues correlates with swimming ability and modulation, while shared 5HT7 expression in DV swimmers indicates that swimming evolved independently using parallel gene expression. Identification of differentially expressed neuromodulator receptor genes in single neurons helps explain how species-typical behaviors evolved.

36.1 TANGWANCHAROEN, S*; BURTON, RS; Scripps Institution of Oceanography, UCSD; *stangwan@ucsd.edu*
Divergence in cis-regulatory elements and HSPB1 gene expression along a temperature cline in the copepod Tigriopus californicus
Conspecific populations may experience substantial variation in thermal environments across the species range and this may result in the evolution of population differences in thermal tolerance. Previous work on the intertidal copepod *Tigriopus californicus* has shown that southern populations can survive acute thermal stress that is lethal to northern populations. These differences are associated with differences in expression of heat shock protein (HSP) genes. Among these genes, HSP Beta 1 (HSPB1) shows the highest level of upregulation and heat tolerant populations also express more HSPB1 than heat sensitive populations. An RNAi knockdown study found that HSPB1 is essential for *T. californicus* survival following acute heat stress. Comparison of approximately 1 kb of 5' flanking region of the HSPB1 gene from populations along the coast revealed variation in Heat Shock Transcription Factor (HSF) binding motifs called Heat Shock Elements (HSEs). HSPB1 promotors from heat tolerant populations contain two canonical HSEs while less tolerant populations have mutations in these conserved motifs. To examine the potential role of sequence divergence in these cis-regulatory elements, we investigated allele specific expression in F1 hybrids between a heat tolerant San Diego population and a less tolerant Santa Cruz population using RNA-seq. The results show biased expression favoring elevated expression of the San Diego allele possessing the canonical HSEs and confirm our prediction of adaptive divergence in cis-regulatory elements. Our results provide an insight on how small changes in cis-regulatory elements could result in different thermal tolerance phenotypes and local adaptation.

107.3 TANNER, JC*; BEE, MA; University of Minnesota; *tanne123@umn.edu*
Sources of Noise-Induced Communication Errors in Hyla chrysoscelis, Cope's Gray Treefrog
Noise is any factor that interferes with a receiver's ability to detect or decode a signal; it is a ubiquitous feature of communication. In natural listening conditions, noise may fundamentally change the strength and shape of selection imposed by receivers in contexts such as mate choice. Two biologically relevant sources of noise in *H. chrysoscelis* are "ambient" noise caused by conspecifics and "signaler" noise caused by within-individual variation in signal production. In phonotaxis tests, we measured the effects of this noise on female preference functions for two critically important signal components: pulse rate, used in species recognition, and call rate, used in assessing male quality. Noise increased receiver error rates, with receivers making the most errors in high levels of noise and when alternative signals had similar trait values. As predicted, females made more errors with respect to male quality (call rate) than species identity (pulse rate). These results suggest 1) receiver error alters the shape of female preference functions and decreases the strength of sexual selection, and 2) past selection has acted to minimize species recognition errors.

51.6 TANNER, RL*; ARMSTRONG, EJ; SOUSA, WP; STILLMAN, JH; Univ. of California, Berkeley, Univ. of California, Berkeley, San Francisco State Univ. Romberg Tiburon Center; *rtanner@berkeley.edu*
Locally adapted Phyllaplysia taylori populations in Central California show higher thermal plasticity potential
Nearshore eelgrass habitats along the Pacific coast of North America play an important role in erosion control, fish and invertebrate development, and local biogeochemical processes. A key grazer in these ecosystems is *Phyllaplysia taylori*, a sea hare living on the *Zostera marina* eelgrass blades that cleans blades of epiphytic algae, diatoms, and bryozoans, allowing for increased photosynthesis and growth. *P. taylori* has direct development, evident in ecological surveys indicating limited dispersal potential. Isolated populations from Grays Harbor, WA to Morro Bay, CA were tested for local adaptation in thermal tolerance plasticity, calculated as acclimation response ratios of upper thermal limits (CT_{max} ARR); upper limits were recorded as high as 35°C. Sea hares were subject to a 4°C/hour ramp and monitored for muscle failure, when they are unable to perform their ecological function. Populations from Humboldt Bay, CA and San Francisco Bay, CA had the highest ARRs over the range of 13°C-21°C (ARR=0.46, 0.38). Differences in the ARR between sites were most parsimoniously explained by a linear model with ecological factors of eelgrass length and frequency, epiphytic coverage, and location found (ΔAIC=0). Evidence of local adaptation in thermal plasticity is strong, as the ARR was best explained by differences in ecological factors, not latitude. Our results suggest that mid-range populations have the greatest potential for thermal acclimation and therefore a greater chance of persistence under future climate scenarios. Since *P. taylori* plays a key role in eelgrass health, understanding local differences in thermal plasticity will have significant implications for eelgrass restoration efforts under future ocean warming.

P1.18 TAPIA, E. *; ANDERSON, S.; CRUZ, P.; FOLKS, N.; JOHNSON, M.; LOUBRIEL, D.; NIEDZIALEK, O.; PEREZ, M.; TRAVIS, D.; GONZALEZ, V.; BARTHELL, J.; University of Central Oklahoma, University of Kansas, Montclair State University, University of Texas at El Paso, Dickinson College, University of Puerto Rico at Rio Piedras, Bard College, Boston University; *etapia@uco.edu*

Creating Context for Undergraduate Research: Embedding Journalism in an REU Program in the Republic of Turkey and Greece

The Research Experiences for Undergraduate Program funds undergraduate research activities among institutions across the United States, but only a small percentage of these grants fund international research. Since 2006, the University of Central Oklahoma has been the Principal Investigator Institution for integrative biological studies of the honey bee, *Apis mellifera* L., in the Republic of Turkey and its border regions. The program integrates the historical and cultural aspects of the geographic regions within which student participants work on their research. Last year (2016), a unique opportunity arose to embed an undergraduate journalism student in the program in order to document and publish activities associated with the project. This effort resulted in two articles in the state of Oklahoma's largest circulating newspaper, The Oklahoman, which included a front page article on honey bees and an account of the socio-economic circumstances that currently surround this region of the world. In addition, the student had a daily online journal published on The Oklahoman's website, documenting the research being done by each student and faculty member. During the summer of 2016, student participants witnessed several events that shaped a unique, international experience. By documenting these experiences, the program has drawn a greater connection between the scientific aspects of the project and the context within which international research occurs. We describe these experiences with commentary on the value of journalism in promoting a broader public appeal to the scientific process and its outcomes for society.

P2.268 TARRANT, A/M*; HELM, R/R; SALANGA, M/C; WHOI; *rrhelm@gmail.com*

Visualizing the cellular redox state in the sea anemone Nematostella vectensis

Reactive oxygen species (ROS) can produce major physiological challenge for organisms (oxidative stress) but also serve as important cellular signals. Recent development of genetically encoded redox indicators (GERIs) has provided unprecedented capability to visualize the oxidative state of cells and tissues in vivo, with the potential to provide insight into the role of ROS signaling in diverse developmental and physiological processes. In many species, cellular redox is known to play an important role in stem-cell maintenance, wound healing, and regeneration. In addition, the oxidation state of certain proteins is a ubiquitous feature of circadian rhythms, but the extent to which cellular or subcellular redox state may fall under circadian regulation is unknown. The cnidarian *Nematostella vectensis* is naturally exposed to drastic changes in salinity, temperature, UV exposure, and anoxia, however, variation in its cellular redox state has not been described. As a tool for probing ROS signaling in *N. vectensis* under diverse conditions, we synthesized capped mRNA encoding roGFP2 conjugated to either a glutaredoxin (Grx1) or the yeast Orp1. Within these constructs, roGFP2 exhibits a change in excitation spectrum in response to changes in glutathione redox state (Grx1) or hydrogen peroxide concentration (Orp1). As a ratiometric indicator, roGFP2 is well-suited to in vivo imaging because results are not biased by variation in basal expression levels. We injected *N. vectensis* zygotes with each of these constructs and observed strong transient expression that persisted throughout embryonic and larval development into the juvenile polyp stage. We determined that these protein constructs are responsive to changes in redox state by imaging embryos before and after hydrogen peroxide exposure. We will use these tools to understand diverse features of *N. vectensis* biology, with a particular focus on development and circadian physiology.

36.4 TASSIA, MG*; WHELAN, NV; HALANYCH, KM; Auburn University, Auburn University, US Fish & Wildlife Service; *mgt0007@auburn.edu*

Evolution and Conservation of Deuterostome Toll-like Receptor Pathways

Knowledge of immune systems is largely derived from work on well-established model species such as fruit fly, nematode, mouse, and human. These taxa have been instrumental in developing our current understanding of the molecular underpinnings of innate immunity; however, these species alone do not provide a phylogenetic distribution sufficient for illuminating evolutionary patterns in the evolution of immunity. Toll-like receptors (TLRs) and their associated signaling molecules represent ancient innate immunity mechanisms for pathogen-associated molecular pattern recognition among metazoans. To understand how these mechanisms have evolved and differ in deuterostomes, we sampled TLRs and associated gene across 37 species hemichordates, echinoderms, cephalochordates, tunicates, and vertebrates using transcriptomic and genomic information. Our data reveal the canonical signaling pathway, deemed MYD88-dependent, is conserved among deuterostomes with the single exception of the downstream signaling mediator TAB2. Proteins indicative of specialized/alternative signaling pathways also appear to be present among cephalochordates and hemichordates, despite previous findings suggesting specialized TLR signaling pathways may be specific to the vertebrates. Finally, we find strong phylogenetic support for conserved TLR3 orthologs - the mammalian TLR responsible for binding viral dsRNA - among all deuterostome phyla (except for tunicates which possess a reduced complement of TLRs). This research not only informs the extent of conservation and innovation of deuterostome TLRs, but also strengthens our foundation for understanding the molecular platform on which vertebrate adaptive immunities were established.

P3.35 TAYLOR, SJ*; GRAY, WA; ZIMMERMAN, LM; Millikin University; *sktaylor@millikin.edu*

In vitro synergistic bactericidal activity between antibiotics and Trachemys scripta elegans plasma

The present study aims to provide more insight into the use of antibiotics in order to reduce the amount of antibiotics used to prevent the rise of additional antibiotic resistant bacteria. The in vitro synergistic bacterial elimination of streptomycin and *Trachemys scripta elegans* plasma was studied. Four-hour time kill assays were conducted to determine the bactericidal capacities of turtle plasma, streptomycin, and the two combined against *Salmonella typhimurium* and *Escherichia coli*. Different concentrations of *T. scripta elegans* plasma and streptomycin were tested. Streptomycin showed a higher bactericidal capacity in the presence of turtle plasma. Killing occurred at plasma concentrations as little as 1:40 when in the presence of 0.25 the minimum inhibitory concentration of streptomycin. It is suggested that factors of the humoral immune system, such as complement and natural antibodies, account for the synergistic bactericidal capacity of streptomycin on both gram-positive and gram-negative bacteria. This study demonstrates that *T. scripta elegans* plasma could be a potential treatment option to reduce the use of antibiotics.

S6.8 TAYLOR, Ryan C.*; HUNTER, Kimberly L.; Salisbury University / Smithsonian Tropical Research Institute, Salisbury University; *rctaylor@salisbury.edu*

Timing is everything: Audio-visual integration of signals in the túngara frog

Multimodal signaling is common in communication systems. Depending on the species, individual signal components may be produced synchronously as a result of physiological constraint (fixed) or each component may be produced independently (fluid) in time. For animals that rely on fixed signals, a basic prediction is that asynchrony between the components would degrade the signal, reducing receiver response. Male túngara frogs, *Physalaemus pustulosus*, produce a fixed multisensory courtship signal by vocalizing (whine + chuck call) and inflating a vocal sac. Using a robotic frog, we tested female preferences for variation in the temporal arrangement between acoustic and visual components. When the visual component lagged the call, females largely rejected the multisensory signal. However, this rejection of the asynchronous multisensory signal only occurred when the visual cue followed a full whine-chuck call. When the chuck component was removed, females reversed preference and responded positively to the asynchronous multisensory signal. These data show that asynchrony of a normally fixed signal does reduce receiver responsiveness. The magnitude and overall response, however, depend on specific temporal interactions between the acoustic and visual components. This suggests that female frogs express a degree of plasticity for temporal variation in male signals.

108.7 TAYLOR, BK*; LOHMANN, KJ; Air Force Research Laboratory, University of North Carolina at Chapel Hill; *brian.taylor.48@us.af.mil*

Validating a model for detecting the magnetic field using simulated and hardware approaches

Several animals use properties of Earth's magnetic field as a part of their navigation toolkit to accomplish tasks ranging from local homing to continental migration. Studying these behaviors has led to the postulation of both a magnetite-based sense, and a chemically based radical-pair mechanism. Several proposed models are aimed at both understanding these mechanisms, and offering insights into future physiological experiments. The present work mathematically implements and advances a previously developed conceptual model for sensing and processing magnetite-based magnetosensory feedback by using dynamic neural fields, a computational neuroscience tool for modeling nervous system dynamics and processing. The conceptual sensory model is implemented in both a computer simulation, and engineered hardware, and the same processing architecture is used to process data from both sensing paradigms. Results from the simulation and hardware both show qualitative agreement with each other, and are consistent with the conceptual model's predictions, supporting the model's plausibility. Specifically, a population of magnetoreceptors in which each individual can primarily sense directional information can encode magnetic intensity en masse, while multiple populations can encode both magnetic direction, and intensity. This work can serve both as an analysis and testing tool for biomagnetic reception, and as a design tool for developing new engineered systems.

P3.212 TAYLOR-BURT, KR*; BIEWENER, AA; Harvard University; *karitaylorburt@fas.harvard.edu*

A duck out of water: Hindlimb kinematics during aquatic vs terrestrial takeoffs in mallard ducks, Anas platyrhynchos

The avian hindlimb plays an important role in takeoff by helping to launch the bird into the air. During terrestrial takeoffs, hindlimb function resembles a ballistic jump. Many birds require long water runways for aquatic takeoffs. However, mallard ducks are capable of nearly vertical takeoffs from both water and land. In this study, we measured the kinematics of the mallard hindlimb during terrestrial and aquatic takeoffs. Force production varies between terrestrial and aquatic media. Hindlimb force production during a terrestrial jump depends on muscle force output, while the hydrodynamic force produced by moving the foot through water depends on the square of the hindlimb velocity. We expect that hindlimb kinematics vary between takeoffs from water and land, with the former favoring higher velocities. Preliminary data (n=2 animals with 3 terrestrial and 3 aquatic trials per animal) suggest that while angular excursions at the metatarsal phalangeal joint are similar between terrestrial and aquatic takeoffs, the ankle undergoes larger angular excursions during aquatic (~96 °) than terrestrial (~79 °) takeoffs. The duration of aquatic takeoffs (~0.10 s) is similar to or shorter than terrestrial takeoffs (~0.12 s). Thus, angular velocity at the ankle is higher during aquatic takeoffs (~1000 °/s) than terrestrial (~650 °/s), which is consistent with our hypothesis that takeoffs from water will favor larger hindlimb velocities than from land. These results raise interesting questions about the relative contribution of hindlimb force production for aquatic *vs* terrestrial takeoffs and about the function of ankle extensors, which must power both behaviors that require either high force output (terrestrial takeoff) or high shortening velocity (aquatic takeoff).

85.3 TELEMECO, R.S.*; LANGKILDE, T.; SCHWARTZ, T.S.; Auburn University, Pennsylvania State University; *rst0011@auburn.edu*

Contrasting lizard response to fire ant and heat stress using physiological and transcriptomic measures

Organisms must combat multiple environmental stressors throughout their lives. Although stress is commonly discussed as a single process, whether or nor an organism responds in a similar way to diverse stressors is largely uncertain. To shed light on this uncertainty, we experimentally examined the response of lizards (*Sceloporus undulatus*) to diverse ecologically-relevant stressors: near-critical heat exposure and fire ant attack. We compared both the physiological response (plasma corticosterone and glucose) and transcriptome response in blood and liver to both stressors. In doing so, we address (1) if a transcriptomic signature to stressors can be detected in blood, (2) the degree to which this signature is stressor-specific, and (3) how transcriptomic responses to stressors correlate with physiological responses.

123.3 TENNETT, KA*; COSTA, DP; FISH, FE; West Chester Univ., PA, Univ. of California, Santa Cruz; *kt753341@wcupa.edu*

Terrestrial Locomotion of a Massive Amphibious Mammal: Constraints of Northern Elephant Seals on Land

In the transition from terrestrial to aquatic habits in marine mammals, there has been a change in morphology that has placed constraints on the ability of these animals to continue to function on land. The amphibious northern elephant seal, *Mirounga angustirostris*, is the second largest phocid seal reaching 2,300 kg. Although elephant seals are proficient swimmers and deep divers, their extreme size can limit terrestrial movement. The kinematics of terrestrial locomotion in northern elephant seals were analyzed from video recordings of animals observed on the beach of Año Nuevo State Reserve, CA. The seals moved by dorsoventral spinal flexions. The traveling spinal wave moved anteriorly along the body with the chest, pelvic region, and foreflippers serving as the contact points with the ground. The hind flippers were not used. The spinal wave and foreflippers were used to lift the chest off the ground as the body was pushed forward from the pelvis and the foreflippers were retracted to pull the body forward. Seals moved over land at 0.36-2.55 m/s. Frequency of spinal flexions displayed a direct significant relationship with speed. Contact with the ground differed between the foreflippers and pelvic region as the duty cycle ranged from 0.55-0.96 and 0.12-0.53, respectively. The duty cycle for both foreflippers and pelvic region decreased with increasing speed. The trade-off for the northern elephant seal has been that its massive size and morphology have well adapted it to an aquatic existence, but limited its locomotor performance (i.e., speed, endurance) on land.

P1.210 TESTAGROSE, CT*; HOFFMANN, SL; PORTER, ME; Florida Atlantic University; *shoffmann2014@fau.edu*

Anatomy and flexural stiffness of shark pectoral fins in an ecomorphological context

Shark pectoral fins are comprised proximally of basal cartilaginous elements that articulate with the coracoid and distally of radial cartilaginous elements and thin, flexible ceratotrichia that overlay the radials. The extent of radials into the fin is known to vary among species, where fins with radials that extend less than 50% into the fin are termed aplesodic and greater than 50% into the fin are called plesodic. Here we examine the skeletal anatomy and flexural stiffness from pectoral fins of 21 species of shark. We hypothesize that there is a range from aplesodic to plesodic, rather than two distinct conditions, that correlates with ecology. We hypothesize that benthic sharks have flexible aplesodic fins useful for gripping the benthos and digging in the sand, whereas pelagic sharks have rigid plesodic fins used to generate lift while swimming. We modeled pectoral fins as cantilever beams by immobilizing the proximal end and applying a load to the free end to determine flexural stiffness (EI). We then dissected each fin to determine how flexural stiffness correlates to skeletal anatomy. We found that coastal-pelagic species such as thresher (*Alopias vulpinus*) and silky (*Carcharhinus falciformis*) sharks had the highest flexural stiffness and radials that extended the furthest distally, whereas benthic-coastal species of sharks such as the bonnethead (*Sphyrna tiburo*) and Atlantic sharpnose (*Rhizoprionodon terraenovae*) had more flexible fins with radials that do not extend as far distally. Our data describe a range of pectoral fin anatomy from aplesodic to plesodic and support our hypothesis that the skeletal anatomy and flexural stiffness of shark pectoral fins correlate to ecology. Based on our data, we further hypothesize that pectoral fin function will also be highly variable and correlate with fin anatomy among species.

122.5 TEZAK, B/M*; SIFUENTES, I; WYNEKEN, J; Florida Atlantic University; *btezak@fau.edu*

Can the Sex of Sea Turtle Hatchlings be Identified via Blood Samples?

In marine turtles, sex is determined based on the environmental factors that an embryo experiences during incubation, in particular temperature. The pattern of temperature-dependent sex determination (TSD) is hot female, cool male. Because sex determination in turtles is so closely linked to environmental conditions, the most common prediction associated with climate change is that marine turtles will be at a higher risk of extinction if sex ratios become dramatically female-biased. These concerns highlight the importance of identifying current and historical sex ratios at sea turtle nesting beaches. Estimating hatchling sex ratios at rookeries remains imprecise due to the lack of sexual dimorphism in young marine turtles and delayed sexual maturity. Most common practices for estimating sex ratios are indirect, based on nest temperatures, air and sea surface temperatures, incubation duration and estimated thermosensitive period durations. However, there is insufficient evidence that these proxies indeed result in realistic primary sex ratios from natural sea turtle nests or rookeries. The lack of a simple, nonlethal technique to verify the sex of hatchlings is at the foundation of this problem. The purpose of this study was to develop a technique to identify sex in loggerhead sea turtle (*Caretta caretta*) hatchlings via analysis of blood samples. We used Western blots to detect the expression of several proteins known to play an important role in sex differentiation in hatchling blood samples. The presence of these proteins were then compared to the results from laparoscopic or histological procedures in order to validate this approach. Finding a sex-specific marker in hatchling turtle blood samples would allow for large scale measurements and verification of naturally occurring sea turtle sex ratios; a crucial step in assessing the impacts of climate change on turtle demographics.

P1.152 TEZAK, B/M*; SIFUENTES, I; LOLAVAR, A; WYNEKEN, J; Florida Atlantic University; *btezak@fau.edu*

Temperatures Inside and Outside of Turtle Eggs

For turtles, the thermal environment that the embryo experiences during incubation plays a critical role in many biological processes. Sex ratios of species with temperature dependent sex determination are often estimated based on such values. The most common practices for measuring sex ratios on sea turtle nesting beaches use proxies that estimate the sex ratios indirectly by using nest temperatures, beach temperatures, and incubation duration. However, the environment that the embryo actually experiences is that of the inside of the egg. Here we ask the questions (1) How does the temperature inside of a turtle egg relate to the temperature outside in the nest or incubation medium? and (2) How do thermal measures change under different hydric conditions? *Trachemys scripta* eggs were incubated at constant temperatures (29 °C or 31 °C) and were subjected to either wet or dry moisture treatments. We used thermocouples to measure the temperature inside and outside of the egg as well air temperature over 24h trials. The majority of the embryos remained alive throughout the course of the trials. The procedure for introducing the thermocouple in the egg will be described. While the temperature inside and outside of the egg did not differ, moisture treatments had a significant effect on incubation temperatures. Understanding the relationship between the outside environment and the inside of the egg is key in order to make accurate assumptions about conditions that a turtle embryo experiences during development. Such information is relevant to understanding temperature dependent sex determination as well as embryonic growth.

17.5 THAKUR, N.; HSU, S.; DELACATO, C.; CHENG, B.*; The Pennsylvania State University; *buc10@psu.edu*

Kinematics and Aerodynamics of Forward Flight in Bluebottle Flies: Experiments Using a Magnetic Flight Mill

As many insects are capable of efficient fast forward flight, their flight kinematics and aerodynamics are challenging to study in these flight regimes. In this work, we developed a flight mill based on magnetic levitation to systematically study forward flight in bluebottle flies. In the flight mill, a fly was tethered to one end of a rod which was levitated stably through feedback control of two electromagnets. The flies were allowed to fly on a circular path with a radius large enough so that the flight can be approximated as translational. The flight mill was also enclosed within a set of cylindrical walls with vertical stripes to ensure that each fly received sane visual stimuli during flight. In addition, a thin plate was attached to the other end of the rod, which functioned as a damper that added aerodynamic loading to the forward-flying flies. In the experiment, we systematically varied flies' body pitch angles from 0 to 30 degrees and the aerodynamic loading by varying the size of the damper (no damper, small and large damper). The body and wing kinematics of the flies were recorded by three high-speed cameras. The results show that flight speed was highly dependent on the body pitch angle and the aerodynamic loading. Specifically, the flight speed decreased as pitch angle increased, and it was observed that some flies have difficulty flying at 30-degree pitch angle. The flight speed also decreased as aerodynamic loading increased. We estimated the thrust based on the drag acting on the damper and the rod, which were also used to estimate the required aerodynamic power. It was also found that the flies tilted their wing stroke plane forward and used large asymmetries in wing angle of attack to create thrust.

51.3 THAWLEY, CJ*; BATTLES, AC; MONIZ, HA; MERRITT, A; KOLBE, JJ; Univ. of Rhode Island; *cthawley@uri.edu*

Lizards in the Big City: Impacts of Urbanization on Morphology, Thermal Preference, and Parasitism in Anolis Lizards

Organisms inhabiting urban environments are exposed to novel challenges which may include increased temperatures, exposure to disease or toxins, disturbance, and novel predators. These environments may also present opportunities including novel niche space or abundant resources for some species. Understanding the impacts of urbanization on species that utilize these habitats is important for predicting the impacts of global change and conservation. The brown anole, *Anolis sagrei*, and the Puerto Rican crested anole, *A. cristatellus*, are recent invaders to southern Florida which utilize urban habitats. We assessed impacts of urbanization on morphology (size and body condition), thermal preference, and parasitism (gut and blood parasites) in populations of these species from highly developed habitats and natural forest fragments in the Miami metropolitan area. In urbanized habitats, both species grew larger, but had equal body condition to lizards from natural habitats. *A. sagrei*, but not *A. cristatellus*, experienced higher parasitemia in urbanized habitats. Higher parasite load altered thermal preferences in both species. As such, lizards may experience some benefits, including increased size, in urban areas, but are also subject to potential costs, such as increased parasitism and altered thermoregulation. Our results suggest that urban environments may impose novel pressures on organisms and that these may vary across species.

57.1 THEOBALD, JC*; CURREA, P; Florida International University; *theobald@fiu.edu*

Larval feeding affects visual acuity and sensitivity in adult fruit flies

Holometabolous insects have lives divided into discrete stages, with larvae that are largely dedicated to feeding and growth, and adults that are usually dedicated to dispersal and reproduction. In a laboratory setting holometabolous insects are generally well fed, and therefore reach a large and uniform adult size. But larvae in the wild often rely on ephemeral food sources, subject to the risks of unpredictable desiccation, temperature shifts, competition, and predation. They may often be motivated to pupate earlier, which will result in smaller adult sizes. This carries important consequences, especially for vision, which is highly sensitive to eye size. But despite the ubiquity of uncertain nutrition in the wild, and tremendous study on flight in the lab, these natural allometric effects on fruit fly vision have rarely been considered. We found that wild reared fruit flies have highly variable sizes compared to their counterparts reared in the lab, and that their generally smaller eyes are composed of facets that are both smaller and less numerous. This is significant for an animal with already poor resolution that frequently flies in dim light. Small facets produce less light catch and increased diffraction, while fewer facets reduce spatial acuity and possibly field of view. These changes affect both visual sensitivity and total image information, which in turn compromises the perception of dim, fast, and high frequency spatial patterns.

128.6 THERIAULT, JS*; BAHLMAN, JW; ALTSHULER, DL; University of British Columbia, Vancouver; *jtheriau@zoology.ubc.ca*

The functional role of the intrinsic wing muscles of the pigeon (Columba livia) during dynamic wing morphing

Birds dynamically modulate their wing shape during flight. One example is folding and expanding the wing during the up- and downstroke, and involves flexion and extension of the elbow, respectively. Elbow extension is driven by the two heads of the triceps; scapulotriceps and humerotriceps. However, little is known about the role of these two muscles in actively modulating wing shape. Electromyography recordings (EMGs) in pigeons (*Columba livia*) show activation of the scapulotriceps beginning just prior to muscle peak length, suggesting the muscle functions as an actuator. In contrast, the humerotriceps is activated near the end of muscle shortening, suggesting the muscle could function as a brake. To test these hypotheses, we used an *in situ* work loop technique in pigeons to characterize the performance space of the humerotriceps by sampling a wide range of activation onset times and measuring the net work. We then compared the *in vivo* EMGs to this performance space to propose the *in vivo* role of this muscle. The muscle generated net positive work, indicating it serves as an actuator, between -40% and -15% cycle before peak length. The muscle generated negative work, indicating it functions as a brake, between -5 and 40% cycle before peak length. Comparison to the *in vivo* activation timing (9%) suggests that this muscle is used primarily as a brake, resisting elbow flexion and wing folding. Repeating the study with the scapulotriceps will reveal if the muscle is the primary elbow extensor, or if it also provides a braking role. Assuming the performance space is similar for both triceps, then the *in vivo* activation (-32%) is within positive work output range and the muscle's primary role would be actuation. More research is required to test this hypothesis.

S11.8 THOEN, Hanne H.*; STRAUSFELD, Nicholas; MARSHALL, Justin; University of Queensland, Brisbane, Australia, University of Arizona, Tucson, USA; *h.thoen@uq.edu.au*

Pathways Underlying Colour and Polarisation Processing in Stomatopods

Stomatopods have one of the most complex visual systems amongst all invertebrates. Specialised photoreceptors are arranged in 6 equatorial rows of ommatidia (the midband), dividing the eye in an upper and lower hemisphere. The 6 rows contain receptors detecting 12 spectral channels in addition to circularly polarised light. The hemispheres are achromatic, but detect linearly polarised light. How these information channels are processed remain elusive, although behavioural and neuroanatomical experiments suggest that they may use a processing system different from other animals. The shape and equal spread of the spectral sensitivities (from UV to far red) across investigated species combined with the fact that stomatopods use scanning eye movements also support such a hypothesis. While the stomatopod retina has been carefully examined, little is known about the neural architecture underlying the elaborate retina. Our studies resolve the neuronal pathway from the midband as segregated through the lamina and medulla before being integrated via lateral collaterals with hemispheral information in the lobula. Segregated relays from the lobula then project into the medulla terminals to numerous glomeruli, comparable to optic glomeruli found in insects. Stomatopods appear, however, to have a higher number of glomeruli than insects, even those with sophisticated visual behaviors. In addition, the stomatopod central complex (CX), receiving afferents from the medulla terminalis, also correspond in detail to the CX of insects. Either this is an extreme example of convergent evolution or it reveals genealogical correspondence of hexapod and eumalacostracan brains, implying the retention of complex ancestral brain organization in divergent pancrustacean lineages.

138.2 THOMAS, KN*; VECCHIONE, M; JOHNSEN, S; Duke Univ., NOAA Systematics Lab; *kate.thomas@duke.edu*

What big eyes you have: Eye allometry and visual range in deep-sea cephalopods

Cephalopods generally have large, well-developed eyes, but the sizes of these eyes relative to body mass vary across ontogeny and phylogeny. Eye size is a crucial determinant of visual capability, as a larger eye can improve both sensitivity and resolution and ultimately determines visual range. However, eyes are metabolically expensive and the neural processing associated with vision imposes a significant energetic cost. Large eyes may also be targets for predators. Thus, the environment and visual needs of an organism will determine the cost-benefit balance for eye size. Light in the ocean decreases with depth, making the deep sea a particularly interesting environment in which to investigate eye scaling. Most vertebrates show negative intraspecific allometry, where relative eye size decreases throughout growth within a species, as well as negative interspecific allometry, where relative eye size is smaller in larger-sized species. Eye allometry in cephalopods, however, has not been well-studied. Here, we examine how eye diameter scales with body mass and length throughout growth, and how eye size compares among different species of deep-sea cephalopods occupying different depth regimes. We measured eye diameter, lens diameter, dorsal mantle length, and mass in a variety of species housed in the cephalopod collection at the Smithsonian's National Museum of Natural History. We found variation in intraspecific scaling relationships, with deepwater cephalopods often exhibiting close to isometric eye scaling. We will discuss interspecific variation in allometric patterns, relationships with biome, depth and vertical migration, and ultimate implications for visual ranges of deep-sea cephalopods.

27.3 THOMETZ, NM*; ROSEN, DAS; REICHMUTH, C; Univ. of California Santa Cruz, Univ. of British Columbia; *nthometz@ucsc.edu*

Patterns of Energy Intake in Captive Spotted Seals (Phoca largha) Provide Insight into Physiologically Sensitive Life-Stages

Forecasting the potential impact of environmental change on ice-associated seals requires identifying critical nutritional and physiological periods. To provide fine-scale information about developmental and seasonal changes in growth and caloric requirements, we evaluated two captive male spotted seals (*Phoca largha*) at the University of California Santa Cruz over a six-year period extending from early development through sexual maturity. Daily caloric intake was determined for each individual and referenced to developmental stage (age), physiological condition (body mass and length, reproductive maturity, molting status), and corresponding environmental features (air and water temperatures, photoperiod). The seals displayed highly predictable developmental and seasonal patterns in food intake and body mass, comparable to other temperate and polar seals. Annual peaks in food consumption occurred during the annual spring molt and remained elevated during the post-molt period. Voluntary hypophagia occurred in the winter, although this decline was notably absent in a year with abnormally warm water temperatures. Seasonal cycles in food intake became more acute with age, largely due to more extreme winter hypophagia. These data suggest that seasonal fluctuations in spotted seal prey resource requirements are strongly influenced by both physiological cycles and environmental conditions. Although the absolute amount of prey needed by captive individuals is presumably less than for wild conspecifics, the relative developmental and seasonal patterns in energy intake described in this study are essential to understanding both short- and long-term energetic requirements of wild spotted seals.

S2.10 THOMPSON, M.A.*; KNIGHT-MALONEY, M.; Fort Lewis College; *mathompson@fortlewis.edu*

Physiological and Biomechanical Mechanisms of Distance Specific Human Running Performance.

Running events range from 60m sprints ultra-marathons covering 100mi or more, which presents an interesting diversity in terms of the parameters for successful performance. Here, we review the physiological and biomechanical variations underlying elite human running performance in sprint to ultra-marathon distances. Maximal running speeds observed in sprint disciplines are achieved by high vertical ground reaction forces applied over short contact times. To create this high force output, sprint events rely heavily on anaerobic metabolism, as well as a high number and large cross-sectional area of type II fibers in the leg muscles. Middle distance running performance is characterized by intermediates of biomechanical and physiological parameters, with the possibility of unique combinations of each leading to high-level performance. The relatively fast velocities in mid-distance events require a high mechanical power output, though ground reaction forces are less than in sprinting. Elite mid-distance runners exhibit local muscle adaptations that, along with a large anaerobic capacity, provide the ability to generate a high power output. Aerobic capacity starts to become an important aspect of performance in middle distance events, especially as distance increases. In distance running events, VO2max is an important determinant of performance, but is relatively homogeneous in elite runners. VO2 and velocity at lactate threshold have been shown to be superior predictors of elite distance running performance. Ultra-marathons are relatively new running events, as such, less is known about physiological and biomechanical parameters that underlie ultra-marathon performance. However, it is clear that performance in these events is related to aerobic capacity, fuel utilization and fatigue resistance.

P3.229 THOMPSON, NE*; DEMES, B; OSTROFSKY, KR; MCFARLIN, SC; ROBBINS, MM; STOINSKI, TS; ALMéCIJA, S; NYIT College of Osteopathic Medicine, Stony Brook University, The George Washington University, The George Washington University, Max Planck Institute for Evolutionary Anthropology, Dian Fossey Gorilla Fund International; *nthomp03@nyit.edu*

Biomechanics of Knuckle-Walking in African Apes

Knuckle-walking (KW) is a unique form of terrestrial locomotion utilized only by chimpanzees and gorillas among primates, wherein the dorsal aspect of the manual intermediate phalanges contact the substrate. Little quantitative data documenting the forces and motions involved in KW, or the frequency with which it is utilized over other hand postures, exist for African apes, making it is difficult to evaluate hypotheses regarding the evolution of this unique locomotor behavior. Here we present laboratory-based 3D kinematic and kinetic data of KW in two subadult chimpanzees (*Pan troglodytes*), as well as field-based kinematic descriptions of KW in wild mountain gorillas (*Gorilla beringei beringei*) at Bwindi Impenetrable National Park, Uganda and Volcanoes National Park, Rwanda. Initial data indicate that chimpanzee KW is characterized by a peak vertical force late in stance phase (~70-80%), and fore-aft forces that are largely braking, but are propulsive during the last 10-40% of stance phase. During stance phase the wrist underwent ~25° of flexion/extension which was largely confined to 0-20% and 80-100% of stance, and underwent a range of ulnar/radial deviation of 20-25°. Kinematic data of wild mountain gorillas indicate that though KW is the main hand posture utilized during terrestrial walking (~90% of steps), gorillas also utilize other hand postures, such as dorsal metacarpal weight bearing and fist walking. Together these data form the basis from which we can evaluate hypotheses of the origin of knuckle-walking. Funded by NSF grants SBE 0935321, 1606853, 1520221, Max Planck Society, and the Leakey Foundation.

P3.178 THONIS, AE*; CEBALLOS, RM; TUEN, AA; LEVESQUE, DL; Rensselaer Polytechnic Institute, Troy, NY, Univ. of Arkansas, Fayetteville, Univ. Malaysia Sarawak, Univ. of Maine, Orono; *thonia@rpi.edu*

Small, Hot, and Fuzzy - High Upper Critical Limits and a Large Thermoneutral Zone in a Small Tropical Mammal

As the earth's ambient temperature continues to rise, it is important to understand the relationship between animal metabolism and changing global climates. Thermophysiology is therefore becoming increasingly important in helping to determine how a species will respond to climate change. Surprisingly little, however, is known about thermoregulation of tropical endotherms. To increase our knowledge of the physiology and energetics of tropical mammals, we measured the resting metabolic rate (via oxygen consumption) of free-ranging lesser treeshrews (*Tupaia minor*, order Scandentia) at varying ambient temperatures. Basal metabolic rate was on average 1.26 mL $O_2.hr^{-1}.g^{-1}$, which is within the range predicted for a 65g animal. However, the treeshrews had a surprisingly large (~10°) thermoneutral zone when compared to other species of similar body mass. We calculated a lower critical temperature of 27.3° but could not determine the upper critical temperature using metabolic rates even at temperatures as high as 36°. The treeshrews maintained a large gradient between body temperature (>37° at rest) and the ambient temperatures measured, which were representative of what the species experiences in its environment. Because of this substantial gradient and the species' large thermal neutral zone, we posit that the species will be able to cope with predicted increases in local ambient temperatures. This is in contrast to most tropical ectotherms that are generally predicted to be more vulnerable to changes in climate than their temperate counterparts, and highlights the importance of further research in the tropics.

P1.118 TIATRAGUL, S*; WARNER, D.A; KOLBE, J.J; KURNIAWAN, A; Auburn University, University of Rhode Island, University of Alabama at Birmingham; *stiatragul@auburn.edu*

Embryos of non-native Anolis are robust to urban thermal environments

The transformation of natural habitat worldwide into urban landscape dramatically alters thermal environments, which can impact local biota. Urban areas often provide novel environments that exhibit greater temperature variation than natural areas (e.g., urban heat island effect). Ectothermic organisms that are oviparous are particularly sensitive to these altered environments because their embryos cannot behaviorally thermoregulate and the surrounding environment determines the temperature experienced during development. In this study, we evaluated the effects of incubation temperatures on development and hatchling phenotypes of two non-native lizards (*Anolis sagrei* and *Anolis cristatellus*) from two metropolitan areas of Miami, Florida. To determine if embryos from urban and natural habitats are adapted to their respective thermal environments, we incubated eggs from each habitat using temperatures that simulate likely nest conditions in both urban and natural sites. For both species, urban thermal environments accelerated embryonic development, but had no impact on egg survival or any of the phenotypic traits that were measured (e.g., body size, running performance, and locomotor behavior). Our results provide no evidence that embryos from urban and natural habitats are adapted to their respective thermal environments. Instead, the lack of any major effects suggest that embryos of both species are physiologically robust with respect to novel environments, which could have facilitated their success in establishing in non-native ranges and in human-modified habitats. Future studies on the growth and survival of these hatchlings in the field will help shed light on when adaptation and acclimation might occur.

P3.80 TIEGS, JM; HOESE, WJ*; California State University Fullerton; *bhoese@fullerton.edu*

From Trash to Treasure: The Use of Man-made Debris as Nest Material by Western Bluebirds (Sialia mexicana)

Urban birds often incorporate man-made materials in their nests and these materials often resemble natural materials typically used in nest construction. The use of man-made materials may, however, increase entanglement risk of both adults and nestlings. The western bluebird (*Sialia mexicana*) is a common songbird in southern California that readily nests in nest boxes in open, park-like habitats. We documented the types and amounts of man-made debris and measured entanglement rates in 75 western bluebird nests from four sites (two parks and two cemeteries) in Orange County, CA. We surveyed for man-made debris in the habitat surrounding each nest box. Western bluebirds used long, thin, and flexible plastic, paper, and fabric items that resembled natural materials in their general properties (106 +/-18.8 items/nest, mean +/- S.E.). Easter basket grass was the most commonly found man-made item in nests. Fifty-nine nests contained broad debris for which there was no obvious natural analog. Unlike the flexible, mostly cellophane, broad man-made items, broad natural materials may not fit easily through the nest box opening. Broad man-made objects may serve a novel function lining the cups of western bluebird nests. The amount of man-made material in each nest was not correlated with debris abundance surrounding its nest box; at the site level, however, environmental debris abundance was correlated with nest debris abundance. Of the 262 nestlings monitored only two died of entanglement suggesting that western bluebirds may be at low risk of entanglement and are relatively well suited to urban settings with man-made debris.

27.8 TIELENS, EK*; GRUNER, DS; University of Maryland, College Park; *elske.tielens@gmail.com*

Geological age and host polymorphism affect functional diversity and community composition in plant-insect interactions across a space-for-time chronosequence on the Hawaiian Islands.

Understanding local diversity, turnover and variation in community response to environmental variability across scales are key goals in community ecology. I examine insect community composition and diversity across community succession using a space for time chronosequence. I test the relationship between taxonomic and functional turnover across the chronosequence, and drivers of insect community response to age related host polymorphism. I sampled arboreal arthropod communities on the Hawaiian Islands, where substrate ages range from historic to Pleistocene. Native Hawaiian mesic forests are dominated by the polymorphic tree species *Metrosideros polymorpha*, allowing comparison of arboreal phytophagous insect communities on the same host across age and community development. I use novel model-based methods for multivariate abundance data to analyze community composition and identify traits that drive species variation in environmental response. Results indicate that species richness and abundance peaks at intermediate age high productivity plots. Species turnover between trees on similar substrate ages was lowest at intermediate aged substrates, indicating that these forests may be dominated by a small number of species. Functional diversity increases with species richness but does not saturate within Hawaii. Insect traits predicting abundance in response to host polymorphism across the chronosequence are nymphal location, and feeding guild. Insect traits are strongly correlated with foliar nitrogen and specific leaf area.. These results shed light on the structure of phytophagous insect communities across substrate age and the role of host plant polymorphism for these insects on the Hawaiian islands.

125.3 TIFT, M.S.*; LUEKER, T.J.; ST. LEGER, J.A.; CABRALES, P; JORDAN, P.A.; PONGANIS, P.J.; UCSD, SeaWorld; *mtift@ucsd.edu*

Blowing smoke? Elevated carbon monoxide (CO) in marine mammals

Carbon monoxide (CO) is known for the toxic property of binding tightly to hemoglobin, forming carboxyhemoglobin (COHb), and can prevent oxygen delivery to tissues when COHb values get too high. However, the recent discovery of 1) heme degradation leading to natural CO production in the body, and 2) therapeutic properties from moderate CO exposure has shed new light on the gas. This natural production of CO in the body leads to approximately 0.4 - 1% COHb in non-smoking humans. The most promising therapeutic potential of moderate CO exposure has been attributed reduction in specific conditions (inflammation, apoptosis, cell proliferation) associated with ischemia-reperfusion events. Due to the increased heme protein stores and repetitive ischemia-reperfusion events associated with the dive response in diving animals, we wanted to investigate endogenous CO levels in the breath (ppm CO) and blood (% carboxyhemoglobin - COHb) of four species of cetaceans (Bottlenose dolphins, short-finned pilot whales, killer whales and beluga whales) and two pinniped species (northern elephant seals and Hawaiian monk seals). Our findings show that animals with the most elevated heme protein stores (elephant seals, monk seals and beluga whales) have increased exhaled CO levels (23ppm, 6ppm and 7ppm, respectively) that mimic those seen in human cigarette smokers (> 6 ppm). However, only the elephant seal displayed dramatic elevations in blood CO with values as high as 17.6% COHb (chronic cigarette smoker: 6-15% COHb). These high values are hypothesized to result from elevated erythrocyte turnover in a species with the highest mass-specific mammalian blood volume and hemoglobin concentrations. We suggest that these natural elevations in CO potentially serve to protect the animals against injuries related to consistent ischemia-reperfusion events associated with a lifestyle of breath-holding and the dive-response.

4.5 TIJS, C*; KONOW, N; BIEWENER, AA; Concord Field Station, Harvard University, Concord Field Station, Harvard University; Dept. Biol. Sci. U. Mass. Lowell; *chris_tijs@fas.harvard.edu*

Comparison of Fascicle versus Whole Muscle Contractile Speed within a Compartmentalized Muscle

Traditional one-element Hill-type muscle models are common in musculoskeletal modelling and assume identical biomechanical properties for all fibers of a muscle. The rat medial gastrocnemius (MG) is a pennate and compartmentalized muscle with proximal fibers that are shorter, more angled and less fatigable than distal fibers. These features may be at odds with the assumption of homogeneous fiber mechanics. We used sonomicrometry on an *in situ* preparation in anesthetized rats (n = 3) to evaluate supra-maximal force-velocity properties of three MG structural units: the whole muscle, proximal fascicles and distal fascicles. Isometric optimum length (L_0) was determined for each structural unit and isotonic shortening contractions were elicited at various levels of MG force as controlled and measured by a servomotor. Shortening speed was determined for each structural unit at its specific L_0. Fascicle speeds were normalized to their specific L_0, and muscle speed to the average fascicle L_0. Maximum shortening speed (V_{max}) and power ratio (a force-velocity curvature measurement) were calculated. Whole muscle V_{max} (12.7±1.9 L_0/s; mean±SD) was higher than V_{max} of the proximal (9.9±2.2 L_0/s) and distal (8.7±1.3 L_0/s) fascicles. Power ratio of the whole muscle (0.12±0.01) was similar to that of the proximal (0.12±0.01) and distal (0.12±0.02) fascicles. The presence of relatively slower fibers in the proximal compartment appeared to have negligible effects on fascicle force-velocity characteristics. In line with previous studies, these findings suggest that pennate muscles can partly circumvent fascicle force-velocity constraints and are likely important in considering regional differences in contractile properties. Funded by NIH AR055648 to A.B.

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Evolution of the Timeless Family of Genes: Functional Implications of Duplications within the Daphnia Genus

The timeless family of genes has two general homologs: timeless (*TIMless*) and timeout (*TIMout*, or *TIM2*). *TIMless* appears to have evolved as a duplication of *TIMout* within the early Bilaterian divergence and has a well-established role in circadian rhythmicity in arthropods. *TIMout* is less extensively studied, but recently-discovered roles are numerous and include a conserved circadian function, DNA replication and repair, and developmental processes. The two fully-sequenced genomes of the *Daphnia* genus (Crustacea: Branchiopoda: *D. magna* and *D. pulex*) show a group rich in duplications genome-wide. For example, the timeless genes are abundant with 9 copies in *D. pulex* and 5 in *D. magna*. We have previously determined that all *D. pulex* copies are actively transcribed. Gene duplications can result in pseudogenization, subfunctionalization, or neofunctionalization. We used a computational approach to establish a set of differentiating criteria for TIMless and TIMout proteins that are useful in determining phylogenetic trajectories including conservation of function, functional novelty, and functional degeneration. We then applied these criteria to the *TIM* family duplicates in *Daphnia* to predict their status. Within each species is one intact *TIMless*, one intact *TIMout*, and several duplicates in stages of rapid mutation with at least some potential functional conservation.

P3.226 TINGLE, JL*; HIGHAM, TE; Univ. of California, Riverside; *jessica.tingle@email.ucr.edu*

Morphological Correlates of Sidewinding Locomotion in Vipers

Among vertebrates, snakes are the largest, most diverse limbless radiation, making them a model for studies of convergent evolution in limbless locomotor modes. Of the several types of snake locomotion, sidewinding represents an ideal gait for answering questions of the relationship between morphology, behavior, and the environment, given the strong association with specific substrate types (e.g. sand and mudflats). Additionally, sidewinding has appeared multiple times over the course of snake evolution, providing an opportunity to examine convergence in morphology and function. We examined several species of sidewinding vipers (e.g. *Crotalus cerastes*, *Bitis peringueyi*, *Cerastes cerastes*, *C. vipera*, *Pseudocerastes persicus*, *Eristocophis macmahoni*, *Echis carinatus*, and *E. coloratus*) plus their close relatives to see if distantly-related sidewinding species converge in their morphology. Using museum specimens, we measured snout-vent length (SVL); width and circumference at 25%, 50%, and 75% of SVL; tail length; head length and width; and number of pre-caudal vertebrae. From these measurements, we calculated an elongation ratio by dividing the total length of the animal by the largest of the three width measurements and relative tail length by dividing tail length by SVL. Then, we used a phylogenetic generalized least squares linear regression for multiple traits to determine whether sidewinding predicted any aspects of morphology. We also used a phylomorphospace approach to determine whether sidewinding species generally occupy different regions of morphospace than non-sidewinding species. Preliminary results show that sidewinding species have more vertebrae per unit body length than non-sidewinding species, but that sidewinding may not correlate with a particular body shape.

P3.86 TIPPETT, CM; WARKENTIN, KM*; Frostburg State University, Boston University; *kwarken@bu.edu*

How not to die if its too dry: a comparison of spontaneous and dehydration-induced hatching in red-eyed treefrogs

Eggs face many biotic and abiotic threats, but embryos can escape some dangers by hatching early. Arboreal embryos of red-eyed treefrogs hatch early to escape from acute threats, such as egg-predators and flooding. They can also respond to slow-acting threats such as dehydration, in which the timing of impending mortality is less clear. We compared the timing and process of hatching from dry and well-hydrated eggs. To hydrate clutches, we sprayed them hourly with an automatic mister. We dried clutches at 5-10% below ambient humidity, with infrequent manual spraying. All eggs initially absorbed water from their jelly and swelled, but by age 3 days dry eggs were shrinking. We monitored hatching hourly (age 4.4-6.9 days) and measured the first hatchling from each clutch from photos. We induced other hydrated controls to hatch when dry eggs did, for an age-matched comparison. All clutches hatched gradually, with dry clutches hatching about a day earlier than wet ones. Hatchlings from dry eggs were smaller than age-matched wet controls, and much smaller than later-hatched wet ones. We video-recorded hatching from dry and wet clutches during their peak hatching times. In wet eggs, embryos moved easily in their capsule, showed little clear pre-hatching behavior, and simply ruptured the capsule then rapidly slid out. In dry eggs, most embryos became constrained in one of two positions, and position strongly affected ability to move and hatching success. Many struggled repeatedly in their shrunken capsules before breaking free, but exhibited no body compression during exit, suggesting they made large exit holes. Hydration-dependent differences in the physical structure of egg capsules combine with ontogenetic changes in embryo abilities to generate variation in the hatching process.

S2.3 TOBALSKE, BW*; JACKSON, BE; DIAL, KP; Univ. of Montana, Missoula, Longwood Univ., Farmville, VA; *bret.tobalske@mso.umt.edu*

Ontogeny of Pectoralis Function and Flight Capacity in Birds

Flight is the defining characteristic of birds yet the mechanisms through which flight ability develops are virtually unknown. Wing-assisted incline running (WAIR) and controlled flapping descent (CFD) are behaviors that may offer significant adaptive benefits to developing birds and offer an opportunity to measure the development of pectoralis contractile behavior during the ontogenetic transition toward powered flight. In this study we used WAIR and CFD to measure function in the pectoralis muscles of precocial chukar and semi-altricial pigeon. Using indwelling electromyography (EMG), sonomicrometry, and surgically implanted strain gauges to measure muscle force (in the pigeon), we offer the first comparative data on the ontogeny of flight muscle function. Flapping chukar chicks use near-continuous activation at low amplitudes for the first eight days, and progress to stereotypic higher amplitude activation bursts by day 12. The muscle also undergoes increasing strain at higher strain rates with age, and length trajectory becomes more asymmetrical and saw-toothed. At 20-25 days (12-15% adult chukar mass), pectoralis activity and locomotor performance approaches that of adults, although strain rate exhibits a temporary decrease at 61 d.p.h. concurrent with using newly-replaced primary feathers. Pigeon chicks demonstrate similar trends, including force production that correlates with increasing EMG amplitude, but their capacity to use WAIR and CFD occurred much later in development (5-8 weeks after hatching) and at larger relative sizes (50-70% adult mass). Mass-specific power, peak stress, strain, strain rate and work-loop shape factor in juvenile pigeons were all within the range of adult values exhibited during WAIR or descending flight. NSF IOS-0923606 and IOS-0919799.

116.4 TOBLER, M*; BARTS, N; PASSOW, CN; GREENWAY, R; KELLEY, JL; Kansas State University, Washington State University; *tobler@ksu.edu*

Evolution and Expression of Oxygen Transport Genes in Replicated Lineages of Sulfide Spring Fishes

Hydrogen sulfide (H_2S) is a natural toxicant that creates extreme environmental conditions in some aquatic environments. Its toxic effects primarily result from the inhibition of the mitochondrial respiratory chain and the suppression of aerobic ATP production. Some metazoans have adapted to H_2S-rich environments through increased H_2S detoxification ability, structural changes of toxicity targets in the respiratory chain, and symbioses with microbes. However, H_2S interacts with a variety of biological molecules, and it remains largely unexplored whether adaption also involves modification of alternative molecular targets. For example, H_2S binds to the oxygen transport proteins myoglobin and hemoglobin, which renders them nonfunctional. This is particularly relevant because sulfidic environments are also hypoxic. We investigated twelve evolutionary independent lineages of fish (family Poeciliidae) that have colonized sulfide springs throughout the Americas, including the genera *Gambusia*, *Limia*, *Poecilia*, *Pseudoxiphophorus*, and *Xiphophorus*. Using RNA-sequencing data, we compared the expression of hemoglobin and myoglobin genes between sulfide spring populations and closely related populations in adjacent non-sulfidic environments. In addition, we tested for positive selection on oxygen transport genes in sulfide spring lineages. Our results show upregulation of genes encoding for oxygen transport proteins. In addition, some lineages of sulfide spring fishes exhibit elevated rates of non-synonymous amino acid substitutions, suggesting that oxygen transport genes are under selection. In combination with previous research, our study suggests that adaptation to H_2S-rich environments involves modification of multiple physiological pathways.

S6.10 TOMASZYCKI, M.L.*; ATCHLEY, D.; TOMASZYCKI, Michelle; Lafayette College, Wayne State University; *tomaszym@lafayette.edu*

Nonapeptides, Vocal Communication, and Social Relationships

Social relationships are complex, involving individual recognition and the production and comprehension of many social cues that guide the close coordination of behavior between two or more individuals. The nonapeptides oxytocin and vasopressin are widely believed to regulate social relationships. These findings come largely from prairie voles, in which nonapeptide receptors in olfactory neural circuits drive pair bonding. This research is assumed to apply to all species. However, qualitative evidence at first suggests that nonapeptide receptor distributions are very different between monogamous rodents (olfactory species) and monogamous birds (vocal/auditory species). Previous reviews have offered two competing hypotheses. The work of Sarah Newman has implicated a common neural network across species, the Social Behavior Network. In contrast, others have suggested that there are signal modality-specific networks that regulate social behavior. Our research focuses on evaluating these two competing hypotheses in the zebra finch, a species that relies heavily on vocal/auditory signals for communication, specifically the neural circuits underlying singing in males and song perception in females. We have demonstrated that the quality of vocal interactions is highly important for the formation of long-term monogamous bonds in zebra finches. Additionally, we have shown that social bonding behaviors are not only correlated with activation of nonapeptide receptors in vocal and auditory circuits, but also involve regions of the common Social Behavior Network. Thus, we highlight converging mechanisms of social relationships and also point to the importance of studying multiple species to understand mechanisms of behavior.

P1.169 TORSON, A/S*; NASH, S/A; YOCUM, G/D; RINEHART, J/P; BOWSHER, J/H; North Dakota State University, USDA-ARS, USDA-ARS; *Alex.S.Torson@ndsu.edu*

The long winter: oxidative stress and chill injury in the alfalfa leafcutting bee, Megachile rotundata

Periodic exposure to low temperature stress throughout an insect's life cycle can lead to deleterious physiological effects known as chill injury. Chill injury is characterized by a variety of downstream physiological responses such as metabolic imbalance, disruptions in ion homeostasis, and oxidative stress. Interestingly, when chill-susceptible insects are exposed to brief pulses of increased temperature each day (fluctuating thermal regimes; FTR), survival increases dramatically. Previous assessments of transcriptomic-level responses to FTR, relative to constant chilling, in the alfalfa leafcutting Bee, *Megachile rotundata* show little overlap in expression profiles across life stages, suggesting discrete mechanisms driving the beneficial effects of FTR across developmental stages. Although gene expression across life stages is highly variable, several functional classes of differentially expressed transcripts were still shared across life stages, including those that suggest an oxidative stress response. Here we present assessments of total antioxidant activity, DNA/RNA damage, protein carbonylation, and lipid peroxidation between FTR and constant temperature exposure in both prepupae exposed to an extended overwintering and pupa exposed to a cold snap during spring development.

134.2 TOWNSEND, JP*; SWEENEY, AM; University of Pennsylvania; *townj@mail.med.upenn.edu*

From Blushing Beroids to Tenacious Tentaculata: New Evidence of Tyrosine Metabolites in Ctenophores and Their Functional Implications

Ctenophores have taken on new importance in revealing animal origins with modern work showing their position near the root of the metazoan tree, but an increased interest in this understudied group has also revealed new mysteries. Notably, ctenophore tyrosine metabolism is peculiar: the group lacks the conserved enzymatic machinery to produce catecholamine neurotransmitters from tyrosine and the gene for tyrosyl tRNA ligase is missing. We show evidence both for the presence of tyrosine metabolites and for their functions in several contexts in ctenophores, plausible given that the ctenophore genome encodes uncharacterized tyrosinases. First, the colloblast adhesive of tentacular ctenophores may be L-DOPA based, similar to mussel byssus. We also found immunohistochemical evidence suggesting DOPA's presence in the subepithelial nerve net. We also examined Beroid ctenophores and found evidence of tyrosine metabolites in the epithelial pigments via UV-Vis, Raman, FTIR, and EPR spectroscopy. Taken together, these findings suggest that ctenophores have the ability to metabolize tyrosine into useful o-diphenol and o-quinone derivatives such as DOPA and dopachrome independent of the dopamine biosynthetic pathway, and use them in a variety of biochemical and physiological contexts. We show that ctenophores' noncanonical use of DOPA may shed light on the origins of neurological DOPA signaling in the rest of metazoans.

P1.163 TOXOPEUS, J*; KOSTAL, V; SINCLAIR, BJ; Western University, Ontario, Czech Academy of Sciences; *jtoxopeu@uwo.ca*

Metabolomics and transcriptomics of freeze tolerance acclimation in the spring field cricket, Gryllus veletis

Juveniles of the spring field cricket, *Gryllus veletis*, survive internal ice formation (i.e. are freeze-tolerant) when acclimated under fall-like conditions, while summer-acclimated juveniles do not survive freezing (i.e. are freeze-sensitive). We compare freeze-tolerant and freeze-sensitive *G. veletis* to identify tissues damaged by freezing, and potential mechanisms that protect against or repair this injury. All crickets exhibit fat body damage after a freeze-thaw cycle, but the damage is severe and irreparable in freeze-sensitive crickets, while freeze-tolerant crickets repair the damage within two days of recovery. We identified metabolites that differed in concentration between freeze-tolerant and freeze-sensitive *G. veletis* via metabolomics analyses of hemolymph and fat body tissue, and identified differences gene expression via transcriptomics of fat body tissue from both groups of crickets. We screened metabolites accumulated by freeze-tolerant crickets for their ability to reduce fat body cell damage during *ex vivo* freeze treatments of excised tissue. We then augmented *in vivo* hemolymph concentrations of putative cryoprotectants via injection to determine if they enhanced the ability of whole crickets to survive freezing. These experiments provide a better understanding of the mechanisms that underlie insect freeze tolerance.

27.1 TRACY, CR*; SANDMEIER, F; HUNTER, K; SNYDER, S; WEITZMAN, C; MALONEY, N; NUSSEAR, K; MARLOW, R; HYDE, D; DUPRE, S; MOHAMMIDPOUR, H; Colorado State University, Pueblo, University of Nevada, Reno, Bard College Simon's Rock, Univesity of Nevada, Reno; *dtracy@unr.edu*

Can climate warming offer opportunities to desert tortoises to defend against Mycoplasma agassizii?

Climate change poses a threat to reptiles because hotter thermal environments can preclude times to achieve optimal body temperatures for activity. However, desert tortoises are typically not active during many hours of the day or year during which optimal body temperatures are achievable, and it seems that availability of adequate thermal environments for activity would be abundant even in warmer climates predicted for climate change. Upper Respiratory Tract Disease (URTD) caused by the bacterium *Mycoplasma agassizii* is also a threat to cause extinctions of desert tortoise populations. Our experimental research, and epidemiological theory, illustrate that this host-pathogen relationship is more likely an ancient enzootic relationship that cycles between a commensalism for healthy tortoises, and a pathogenic relationship in tortoises debilitated from too little food and water resources. Additionally, *M. agassizii* can be killed by temperatures that are very warm, but viable to desert tortoises. Thus, tortoises might exploit warm thermal environments to achieve "behavioral fever" to control *M. agassizii*, and climate warming may provide greater opportunities to employ this form of natural immunity. This process for controlling mycoplasmas seems to be limited to the warmer times of the year, but climate warming may increase the times when tortoises could control their pathogen through thermoregulation.

P1.68 TRAN, MV*; MANNING, A; SCHEID, N; Univ. of Cincinnati, Blue Ash; *tranmk@uc.edu*

Dietary Analysis of the Invasive Rusty Crayfish in Their Native Range

The rusty crayfish *Orconectes rusticus* is an invasive species that has undergone significant range expansion throughout the northeastern United States and southern Canada. The omnivorous diet and aggressive behavior of the rusty crayfish make them superior competitors to many of the native species they encounter, and thus rusty crayfish invasion has been shown to cause significant disruptions to the structure of invaded communities. Despite widespread management efforts to limit further expansion of the rusty crayfish, relatively little is known about the dietary requirements of the species. A more in-depth understanding of the dietary requirements of the species is needed to develop more effective management strategies. Furthermore, little effort has been made to study rusty crayfish within their native range where native conditions have shaped their feeding niche. This study aimed to elucidate the food resource use of the rusty crayfish within their natural range of the Ohio River Valley and identify the most important food resources for the species. Specimens of various sizes (and thus ages) of both sexes were collected monthly from the same location in a small, rocky stream in southeastern Ohio. The stomach contents of collected specimens were dissected out and analyzed for diet composition. As expected, detritus was the most frequently observed dietary item. Diatoms were the second most frequently encountered food item, suggesting that rusty crayfish may supplement their scavenging with suspension feeding. Animal tissue was not commonly observed in many of the analyzed stomachs, suggesting that rusty crayfish may be deprived of protein in their natural diet.

S10.7 TRAN, Mai; TSUTSUMI, Rio; COOPER, Kimberly L*; Univ. of California, San Diego; *kcooper@ucsd.edu*

Musculoskeletal integration in hindlimb evolution of the bipedal three-toed jerboa

The limb is a complex structure comprised of muscle, bone, joints, connective tissues, nerves, and vessels. These tissues, with their distinct embryonic origins and genetic programs, must develop coordinately to maintain functionality as the overall structure is reshaped by natural selection. We focus on a bipedal rodent, the three-toed jerboa, as a model to understand the evolution of development of these integrated tissues. The jerboa has a greatly elongated hindlimb, particularly the metatarsals, and completely lacks intrinsic foot muscles. Flexor muscle loss is associated with expansion of the flexor tendons, presumably to absorb landing forces and to prevent hyperextension across the ankle during ricochetal unguligrade locomotion. Surprisingly, we find that nascent intrinsic foot muscles are present in neonates but most disappear rapidly within the first postnatal week as tendon length and cross-sectional area increases. Electron microscopy and immunohistochemistry reveal sarcomeres progressively disassemble with similarities to a variety of human muscle degenerative diseases. However, while few muscle fibers remain after one week, we do not see apoptotic or necrotic cells during stages of fiber loss. Further, while muscle stem and progenitor cells are present in neonatal feet, they fail to repair and regenerate damaged muscle. We are currently adapting viral lineage tracing methods to permanently mark cells of the muscle lineage. These experiments will allow us to test the hypothesis that muscle loss and tendon expansion are connected by transdetermination of muscle progenitors to a tendon fate, perhaps due to early developmental plasticity.

P2.194 TRAVIS, DJ*; GONZALEZ, VH; Boston University, Kansas University ; *djtravis@bu.edu*

Bee Stratification in Western Turkey: Pan Trap Color, Height, and Habitat Preferences

Turkey is home to a great diversity of bees, yet little is known about the biology of the vast majority of species, including their foraging preferences and stratification within environments. I examined height, color, and habitat preferences of a coastal community of bees by constructing stratified pan trap stakes to collect foraging bees. Fluorescent blue, yellow, and white pan traps were placed at three different heights (5cm, 87.5cm, and 175cm) in four unique habitats (forested, edge, agricultural field, and managed/urban) from July 5th to 12th, 2016 in Çanakkale. More bees were collected at the two higher heights than at ground level and yellow traps captured more individuals than other colors. Traps in the field habitat collected more bees than traps in the edge, forest, and urban habitats. The distribution of bees collected from traps of various heights, colors, and habitats suggests a vertical stratification as well as habitat preference within the community of bees sampled.

P1.174 TRAVIS, K*; GRACE, M ; FORD, J; DECKER, S; HUBER, D; The University of Tampa, National Oceanic and Atmospheric Administration, Univ. of South Florida, Morsani College of Medicine, Univ. of South Florida, Morsani College of Medicine; *kevin.travis@spartans.ut.edu*

Structural Mechanics of Cookiecutter Shark Jaws

Cookiecutter sharks *(Isistius spp.)* possess particularly unique feeding mechanisms, behaviors, and ecological niches. Their semi-circular, scoop-shaped lower jaw bears a row of teeth fused into a saw blade, which is used to excise circular flesh plugs from large fishes or cetaceans by engaging the teeth and then rotating the body about its longitudinal axis. The extent to which the constituents of this mechanism facilitate their unique feeding behavior and ecology has not been quantitatively examined. Therefore, we examined the effects of their semi-circular jaw morphology and fused tooth-blade on the structural performance of the jaws. Lower jaw models of *I. brasiliensis* and *I. plutodus* were reconstructed from CT scans and Finite Element Analysis was used to quantify stress and strain energy density in jaws with a) fused tooth rows, b) unfused tooth rows (i.e., teeth digitally separated), and c) no teeth. Forces were applied to the jaws to simulate normal biting (i.e., forces perpendicular to the jaw occlusal surface) and rotational biting (i.e., forces parallel to the jaw occlusal surface). Modeling scenarios were also applied to the spiny dogfish *Squalus acanthias* to determine if the modified cookie cutter shark feeding mechanism facilitates rotational feeding behavior relative to the basal condition for squaliform sharks. Preliminary analyses indicate that lower jaws perform better (i.e., lower stress, strain energy density) during rotational biting, and that the presence of both functional and replacement tooth rows improves structural performance. These results suggest that jaw geometry and dental reinforcement facilitate the unique rotational feeding behavior of cookie cutter sharks.

61.7 TREIDEL, LA*; CLARK, RM; WILLIAMS, CM; UC Berkeley; *lisa.treidel@berkeley.edu*

The effect of diet nutrient composition on development and life history traits of a wing polymorphic cricket, Gryllus lineaticeps

Physiological changes during development cause dynamic shifts in energy and macronutrient demands. Using a wing polymorphic cricket (*Gryllus lineaticeps*), we tested the hypotheses that diet composition differentially impacts performance according to nutrient demands set by ontogenetic stage, and that nutrient preferences shift along with nutrient demands. Morphs of *G. lineaticeps* specialize in dispersal or reproduction. We predicted that dispersal morphs require more protein than reproductive morphs during the last juvenile life-stage (instar) for flight muscle development, but more carbohydrates (carbs) during early adulthood to support flight fuel synthesis. During the last instar or early adulthood, crickets were assigned to one of three *ad libitum* isocaloric diets: 1) choice between protein-biased and carb-biased diets, 2) protein-biased diet (2P:1C), or 3) carb-biased diet (1P:4C). When provided a choice, crickets modulated feeding to optimize nutrient intake. Dispersal and reproductive morphs did not differ in preferred intake. However, preferences shifted throughout ontogeny: juveniles selected a slightly carb-biased diet (Female 4P:5C; Male 7P:10C), while adults preferred a higher protein diet (Female 1P:1C; Male 4P:5C). When fed a carb-biased diet (1P:4C), development time to adulthood was extended and female morph determination was biased to the reproductive morph. Regardless of diet, juvenile dispersal morphs consumed more food than reproductive morphs. Results from this experiment indicate that bulk nutrient intake varies with life history strategy, and that macronutrient composition preferences change during ontogeny. Further experiments will focus on physiological performance consequences of these dietary shifts.

P3.182 TRICOLA, GM*; SIMONS, MJP; KITAYSKY, AS; NISBET, ICT; LANK, DB; SAFRAN, RJ; WINKLER, DW; THOMPSON, PM; VLECK, CM; HAUSSMANN, MF; Bucknell Univ., Univ. Sheffield, Univ. Alaska, Fairbanks, ICT Nisbet and Co., Simon Fraser Univ., Univ. Colarado, Cornell Univ., Univ. Aberdeen, Iowa State Univ.; *gmt004@bucknell.edu*

Telomeres and maximum lifespan in birds

Identifying physiological mechanisms that underlie senescence across taxonomic groups remains a central question in life history evolution. Telomeres are highly-conserved, repetitive nucleotide sequences that protect the ends of linear chromosomes. Telomeric DNA in many cells shortens over time due to the end-replication problem and damaging events such as oxidative stress. Many studies have reported that this shortening is linked to cellular survival and in some cases, organismal survival. However, we know much less about how telomere dynamics relate to aging rates and maximum lifespans across species. We previously reported that avian species who lose less telomeric repeats as they age have longer lifespans than those who lose more. Here, we investigated telomere length in cross-sectional samples from more than twenty known-aged bird species to determine how telomeres relate to species maximum lifespan. All telomere analyses were measured in erythrocytes in our laboratory using the Telomere Restriction Fragment assay. Similar to our previous report, we found that in this larger sample of species, birds with longer lifespans lose less telomeric repeats per year compared to those species with shorter lifespans. Because closely related lineages share many traits in common, our larger sample of species will also allow us to use comparative analyses to control for shared phylogenetic history.

P2.130 TROY, S; University of Texas at Austin; *Savannah.troy@utexas.edu*

Temperature and Nestling Development: Temporal Variations in Zonotrichia leucophrys oriantha Feeding Frequency

Zonotrichia leucophrys oriantha (MWCS) are unique in that their nestlings have a 25% higher metabolic rate than other open-nesting passerines. Nestlings do not develop endothermy until 3-4 days after hatching and are not fully homeothermic until the time they fledge. Thus, MWCS parents must provide for their own metabolic needs and the nestlings' elevated metabolic and thermoregulatory needs in the variable temperatures and harsh conditions of a high-elevation environment. Ultimately, MWCS parents must balance their time between feeding and nest thermoregulation in order for the nest to fledge. I hypothesized that this tradeoff in parental nest attendance behavior varies on colder versus warmer days: feeding rates are reduced and/or delayed on cold mornings and on hot afternoons. These patterns accommodate for incubation during early hours and shading from intense sun during afternoon hours. This was tested by monitoring MWCS nests with data loggers that recorded ambient temperature every two minutes and a nest camera that revealed the frequency of different behaviors. Analysis showed a significant but extremely weak negative correlation between the frequency of feeding and temperature ($R^2 = 0.063831$, $p = 0.0042$) and between the proportion of time parents were absent from the nest and temperature ($R^2 = 0.047224$, $p = 0.0141$). ANOVAs of both temperature with feeding frequency and temperature with parental absence over 3.5 hour intervals revealed that cold mornings have higher feeding frequency but a lower proportion of parental absence than warm mornings. In cold afternoons, there is a higher feeding frequency but an equivalent proportion of parental absence as warm afternoons. However, only the difference in morning feeding frequency is significant ($p = 0.03$). This pilot study shows promise in revealing interesting trends should the sample size be expanded across multiple field seasons.

73.1 TRUEBLOOD, L.A. ; La Sierra University;
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Hot Poop: Temperature and Oxygen Partial Pressure Effects on Salp Physiology

Salps are pelagic tunicates that are found throughout the world's oceans and marginal seas. They play an important role in carbon and food importation into the deep sea as a result of their relatively large, dense, fecal pellets that sink quite rapidly and reach the bathypelagic intact. There is limited understanding of salp physiology, and how it is impacted by environmental changes. Here, I present data from *Salpa fusiformis*, a cosmopolitan species that is known to vertically migrate, and experiences a range of environmental temperatures and oxygen partial pressures. Temperature had a significant effect on routine metabolic rate with mean MO_2 =3.95 ± 0.53 µmol O_2 g^{-1} h^{-1} at 17ºC (n=18), and 1.65 ± 0.17 µmol O_2 g^{-1} h^{-1} at 10ºC (n=15) (ANCOVA, p<0.0001) resulting in a Q_{10} temperature coefficient of 3.48. Additionally temperature appeared to have an effect on critical partial pressure with P_{crit} = 3.4 kPa at 17ºC (n=2) and 1.9 kPa at 10ºC (n=1). Individual zooids were able to consume oxygen below detectable levels in respirometery chambers and recover when reoxygenated at both 17ºC and 10ºC. The observed temperature effect on metabolism and apparent hypoxia tolerance would assist *S. fusiformis* in diurnal vertical migrations in areas with pronounced oxygen minimum zones. Expansion of this work across a broader set of species will help elucidate the impact salps have in carbon cycling in the world's oceans and the influence climate change could have on salp mediated carbon cycling to the deep sea.

P1.178 TSAI, HP*; MIDDLETON, KM; HOLLIDAY, CM; Brown University, University of Missouri; *henry_tsai@brown.edu*

The cartilage cone of archosauromorphs: implications for hip loading and femoral ossification

The cartilage cone is a convex extension of the epiphyseal hyaline cartilage that inserts into the metaphyseal growth plate of long bones. Among extant archosaurs, the cartilage cone results from delayed endochondral ossification relative to perichondral ossification during embryological development, and is absent in neonates. In contrast, the proximal femora of many post-neonatal fossil archosauromorphs bear evidence of cartilage cones. This study investigated the evolution, function, and ontogenetic significance of the cartilage cone in archosauromorphs. Femora of 140 taxa were studied and digitized. Key phylogenetic transitions in cartilage morphology were estimated using likelihood ancestral state reconstruction on the osteological correlates, and analyzed using phylogenetically corrected correlation to reveal trends in body size evolution. The cartilage cone arose independently in multiple archosauromorph lineages but was secondarily reduced in sauropods, theropods, and crocodylomorphs. Although adult body size does not predict the presence of the cartilage cone, it is often absent in large adults but present in locomotor patent conspecific juveniles. The cartilage cone likely provided mechanical support to the thick epiphyseal hyaline cartilage by increasing metaphyseal contact. In sauropods, reduction of the cone coincides with highly rugose growth plates; whereas reduction of the cone in theropods coincides with smooth growth plates. These divergent adaptations are hypothesized to associate with transitions in cartilage thickness and loading regimes. These results indicate that archosauromorphs used uncalcified hyaline cartilage as load bearing tissues on par with subchondral bones, illustrating a key innovation in locomotor tissues.

98.7 TUCKER, EL*; FATH, MA; HSIEH, ST; Temple University, Philadelphia, PA; *liz.tucker@temple.edu*

Compensatory Strategies for Traversing a Drop Perturbation in a Bipedal, Sprawled Runner

Natural terrain constantly challenges locomotor stability. Bipedal parasagittal runners rely on proximo-distal control mechanisms and passive mechanical mechanisms to rapidly adjust to changing environments. However, it is not known how sprawled bipedal runners, like the basilisk lizard, adjust to unexpected perturbations. This study examines how basilisks navigate visible drop perturbations to elucidate the control strategies used to maintain stability. We ran four basilisk lizards along a 2.7 m long trackway with an embedded 6-d.o.f. force plate. Control trials were recorded with the force plate mounted flush to the track surface. We lowered the plate to 40% of the lizards' limb length, relative to the track surface, for perturbation trials. We hypothesized that much like parasagittal runners, basilisks would rely on three distinct compensatory mechanisms to convert the potential energy (PE) change from the drop into fore-aft and vertical kinetic energy (KE) or to increase the total energy of the system (Ecom), as well as a fourth potential mechanism converting PE into medio-lateral KE, as a result of their sprawled limb posture. On average, lizards ran slower (p = 0.0489) and with a more vertical limb posture (p < 0.02) during the drop perturbation. This postural change was reflected in a more vertically-oriented medio-lateral force impulse vector (p = 0.0354). As expected, vertical KE increased in drop surface trials. However, contrary to our hypothesis, the drop perturbation appeared to have little detectable effect on fore-aft and medio-lateral KE. Preliminarily, these results suggest that the sprawled limb posture may afford increased robustness to perturbations such as a sudden drop in surface height, facilitating kinematic compensations independent of significant kinetic changes.

79.2 TUMULTY, J*; BEE, M.A.; Univ. of Minnesota, Twin Cities;
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Reproductive Resource Defense and the Evolution of Neighbor Recognition in Territorial Rocket Frogs

Some territorial animals recognize and respond less aggressively towards familiar neighbors relative to strangers. This common form of social recognition is not found in all territorial species and the social and ecological factors that favor its evolution, as well as the proximate mechanisms that make it possible, are poorly understood. We present results from a comparative study of two closely related species of rocket frogs (Aromobatidae) that defend different types of territories. We quantified habitat use and territory size of individual frogs over a four-year period and found that male golden rocket frogs (*Anomaloglossus beebei*) defend bromeliads for several years, which serve as reproductive resources for eggs and tadpoles. These resources are spatially clumped, putting males in close contact with neighbors. In contrast, male kai rocket frogs (*A. kaiei*), defend single-season calling territories on the forest floor that are not constrained by the distribution of reproductive resources. We tested for neighbor-stranger discrimination in these species with an aggressive threshold playback experiment and found that golden rocket frogs tolerate the calls of familiar neighbors at higher amplitudes than the calls of strangers, whereas kai rocket frogs do not behaviorally discriminate between the calls of neighbors and strangers. Whether neighbor-stranger discrimination in golden rocket frogs evolved in response to the greater value of the defended resource itself, or the greater social complexity that results from defense of clumped resources, is still an open question. Regardless, this system presents a great opportunity to examine the mechanisms of an independently evolved recognition system.

111.2 TUNE, T*; IRVING, T; SPONBERG, S; Georgia Institute of Technology, Illinois Institute of Technology; *ttune3@gatech.edu*
Microstructure of cockroach muscle provides evidence for workloop dependence on actin-myosin spacing
Muscle is a unique material which is capable of performing many different functions, acting as a spring, motor, brake, or strut as characterized by a workloop, a periodically activated force-length curve. What properties of muscle allow for muscle workloop variation? While many determinants of muscle workloops are known (the classic force-length, force-velocity, and twitch response), previous work (Ahn et al., 2006) has identified two muscles in *B. discoidalis* which have nearly identical classical determinants of workloop behavior, but have different workloops. Yet to be examined is the microstructure of these muscles and their relationship to workloops. This can be studied by using x-ray diffraction to measure the spacing and arrangement of myosin and actin under physiological conditions. Using the BioCAT x-ray beamline at the Advanced Photon Source at Argonne NL, we studied the lattice structure of both muscles passively stretched under physiological strains. We first examined their packing structures and determined them to be identical for these muscles. We also found that one muscle's inter-myosin spacing was 1 nm larger than the other's. The largest spacing difference was at high strain, where activation occurs in *vivo*. This is significant because in these muscles' workloops, despite simultaneous activation, the time course of force production following activation is different. Since lattice spacing affects the dynamics of the molecular motors responsible for force production, it's reasonable that lattice spacing changes could be responsible for variation in workloops for these muscles. Previous experimental work (George et al., 2013) and computational models (Williams et al., 2010) suggest even 1 nm lattice spacing differences can be significant in determining muscle work output.

P3.193 TURNER, MD*; ROARK, AM; Furman University; *matthew.turner@furman.edu*
Effects of phytochemical treatment on gonad development of aposymbiotic Aiptasia pallida anemones
Aiptasia pallida is a species of anemone that lives on the Atlantic, Pacific, and Gulf coasts of North America. Like many cnidarians, *A. pallida* anemones harbor intracellular, mutualistic dinoflagellates that provide photosynthetically derived organic compounds to the host in return for inorganic nutrients. Unlike many cnidarians, *A. pallida* can survive without its symbionts in an aposymbiotic state. We recently found that aposymbiotic anemones typically fail to develop gonads or have smaller gonads than symbiotic anemones, suggesting that loss of symbionts constrains sexual reproductive function of the host. The purpose of this study was to evaluate possible non-nutritive mechanisms underlying this finding by exposing aposymbiotic anemones to a variety of phytochemicals for two, 28-day gametogenic cycles. At the end of the second cycle, anemones were anesthetized, fixed in seawater-buffered formalin, embedded in paraffin wax, and sectioned. Serial sections were then alternately stained using either a standard hematoxylin and eosin stain or a modified Masson trichrome stain, and gonad size was measured. Differences in gonad development induced by phytochemical treatment will be discussed.

S7.2 TWEEDT, S.M.; Smithsonian National Museum of Natural History, University of Maryland, College Park; *tweedts@si.edu*
Development and a model for morphology: Phylogenetic applications and the early arthropod fossil record
Developmental regulatory networks govern the construction of morphology and structure how morphological features change through time. Highly conserved networks are often tightly associated with particular features, and similar regulatory patterns can specify similar morphological patterns and character arrangements. Developmental patterns can thus serve as a basis for studying living and fossil morphologies, and may be used to inform morphological character coding and models of character change. Using the fossil ecdysozoan lobopods as a case study, I describe how the developmental underpinnings of morphology may be used to reorganize discrete morphological character data, focusing on how gene network structure translates into a separation of character identity from character states. This reorganization recognizes the biological distinctiveness of "traditional" characters, such as appendages, and of patterning mechanisms which may be re-deployed across multiple body regions, and extends homology beyond a position-specific designation. The lobopods, thought to represent a basal grade leading to extant onychophorans and arthropods, are character-depauperate and difficult to resolve phylogenetically. I explore the contribution of developmental information to the problematic lobopod phylogeny by combining development-based character coding with a Bayesian phylogenetic approach. Because the complex wiring of developmental networks can impose lineage-specific constraints upon the pattern and rate of morphological character evolution, this approach provides a first step in forming a probabilistic model for the evolution of morphology, as well as future application to phylogenetic methods utilizing morphological characters.

121.2 TYLAN, C*; LANGKILDE, T; Pennsylvania State University, University Park; *clh319@psu.edu*
Local and systemic immune response to phytohemagglutinin: Validation of the PHA skin test in the green anole, Anolis carolinensis
The phytohemagglutinin (PHA) skin test is commonly used in ecology to assess the cell-mediated immune function of wild animals, as it can be performed quickly and easily in the field. The nature of the immune response stimulated by PHA skin injection has been studied in many taxa, including mammals, birds, and one amphibian species, but has not been validated in any reptile species. Additionally, there are multiple formulations of PHA used, with potentially differing effects, making it difficult to compare studies. We validated the PHA skin test by comparing the effects of two different forms of PHA in the green anole (*Anolis carolinensis*). At 0, 6, 18, 24, and 48 hours after injection with PHA or a vehicle control, we measured the swelling of the foot, the systemic immune response via a white blood cell count, and performed histological examination of the local immune response. To our knowledge, this is the first study to simultaneously examine local and systemic immune responses to PHA injection. We expect this to provide a more thorough understanding of the effects of PHA on the immune system and, in particular, what aspects of the cell-mediated immune response are stimulated by PHA injection in reptiles.

81.1 TYTELL, ED*; MASSARELLI, N; YAU, A; KIEMEL, T; HOFFMAN, KA; Tufts Univ., Univ. Maryland, Baltimore County, Univ. Maryland, College Park; *eric.tytell@tufts.edu*

Modeling mechanosensory proprioceptive feedback in lamprey locomotion

Sensory feedback is an integral part of the complex closed-loop system of locomotion. Lampreys are model organisms for vertebrate locomotion. Like in all vertebrates, lamprey swimming is driven by a central pattern generator (CPG), a neural circuit located in the spinal cord that produces a pattern of neural activity that activates muscles for swimming. The CPG also responds to proprioceptive inputs that indicate how the body is moving and adjusts its output accordingly. In the lamprey, these proprioceptors are mechanosensory cells called "edge cells", which are located in the margins of the spinal cord. Our goal is to model the sensory inputs from edge cells to the lamprey CPG in order to complete a closed-loop model of lamprey swimming. To identify the response properties of edge cells, we isolated spinal cords of silver lampreys (*Ichthyomyzon unicuspis*) and recorded extracellularly from the lateral tracts. We identified cells that responded to mechanical stimuli and used standard spike sorting algorithms to identify separate units. We used ramp bending stimuli that let us examine how edge cells respond differently to bending velocity as compared to static bending angle. Although some edge cells respond to the bending angle, as was previously known, the strongest and most common responses were to bending rate. We also used Gaussian band-limited noise stimuli and system identification techniques to identify the transfer function between bending and edge cell activity. An under-damped harmonic oscillator with phase dependent forcing that depends on the sinusoidal bending captures key features of the experimental data, and thus can be used to represent the signal from the edge cell to the CPG.

55.6 URACO, AM; HORNAK, J; SELCER, KW*; Duquesne University, Pittsburgh, PA; *selcer@duq.edu*

Distribution of the Enzyme Steroid Sulfatase in Mouse (Mus musculus) and Frog (Xenopus laevis) Tissues

Steroid hormones often travel in circulation as inactive sulfated forms. For example, estrone sulfate and dehydroepiandrosterone sulfate are abundant in human plasma. The enzyme steroid sulfatase (STS) acts to remove the sulfate group, generating active hormones. The role of STS is presumably to provide active steroids to local tissues; however, little is known about which tissues are the major sites of STS activity. This information has implications for understanding steroid hormone physiology and pathology. This study investigated the tissue distribution of STS in two laboratory models, the house mouse, *Mus musculus* and the African clawed frog, *Xenopus laevis*. Tissues included were: heart, liver, small intestine, skeletal muscle and gonads of both genders. An 3H-estrone conversion assay was used to measure STS activity in microsomes and cytosols. In the mouse, liver STS activities were highest for both genders. Testis STS levels were slightly below liver, while ovary, small intestine, heart and muscle STS activities were even lower. For the frog, testis STS activity was highest, with small intestine lower, followed by liver, heart and muscle, respectively. We validated the enzyme activity assay by using two specific STS inhibitors, EMATE and 667 Coumate. Both compounds eliminated STS activity in liver microsomes and cytosols of both species. Liver and testis microsomes of both species had Km values in the reported range for STS. The tissue distributions for STS differ somewhat from those reported for humans. The high values for testis STS in both mice and frogs suggests a potential role for sulfated steroids in testicular steroidogenesis.

S1.9 URBAN, Mark C.; Univ. of Connecticut; *mark.urban@uconn.edu*

Searching for the biotic multipliers of climate change

Predictive models of biotic responses to climate change generally ignore species interactions. Yet, we know that species interactions often mediate climate change responses and extinctions. Understanding how climate affects all species and all of their interactions is impractical given the short time frame over which we need accurate forecasts. One solution is to identify key species that are both highly sensitive to climate change and that have disproportionately large effects on communities and ecosystems. These so-called ‘biotic multipliers' provide the most bang for your buck in terms of spending limited research and conservation dollars. Evidence suggests that biotic multipliers often are top consumers. Top consumers often strongly affect communities and ecosystems through top down effects. However, why might they be more sensitive to climate change relative to lower trophic levels? Metabolic theory suggests one reason. Another hypothesis is that climate-induced food web effects at lower trophic levels combine in ways that increase sensitivity for top consumers. A third explanation is that demographic and life history traits shared by top consumers make them more sensitive to climatic change. Here, I update our knowledge of biotic multipliers and examine evidence for each of these hypotheses. I present several case studies that show how these mechanisms work in natural systems. Lastly, I present a prospectus for future research. This developing framework should help us to make better predictions so that we can mediate changes to biodiversity from climate change.

97.1 USHERWOOD, JR; Royal Veterinary College; *jusherwood@rvc.ac.uk*

Physiological, aerodynamic and geometric constraints of flapping account for bird gaits, and bounding and flap-gliding flight strategies.

Aerodynamically economical flight is steady and level. The high-amplitude flapping and bounding flight style of many small birds departs considerably from any aerodynamic or purely mechanical optimum. Further, many large birds adopt a flap-glide flight style in cruising flight which is not consistent with purely aerodynamic economy. Here, an account is made for such strategies by noting a well-described, general, physiological cost parameter of muscle: the cost of activation. Small birds, with brief downstrokes, experience disproportionately high costs due to muscle activation for power during contraction as opposed to work. Bounding flight may be an adaptation to modulate mean aerodynamic force production in response to 1) physiological pressure to extend the duration of downstroke to reduce power demands during contraction; 2) the prevention of a low-speed downstroke due to the geometric constraints of producing thrust; 3) an aerodynamic cost to flapping with very low lift coefficients. In contrast, flap-gliding birds, which tend to be larger, adopt a strategy that reduces the physiological cost of work due both to activation and contraction efficiency. Flap-gliding allows, despite constraints to modulation of aerodynamic force lever-arm, 1) adoption of moderately large wing-stroke amplitudes to achieve suitable muscle strains, thereby reducing the activation costs for work; 2) reasonably quick downstrokes, enabling muscle contraction at efficient velocities, while being 3) prevented from very slow weight-supporting upstrokes due to the cost of performing ‘negative' muscle work.

P3.211 USHERWOOD, JR; The Royal Veterinary College; *jusherwood@rvc.ac.uk*

An introduction to the Muscle-Mechanical compromise Framework

Many aspects of animal and human gait and posture cannot be predicted from purely mechanical work minimization or entirely based on optimizing muscle efficiency. This poster introduces the Muscle-Mechanical Compromise Framework as a conceptual paradigm for considering the interactions and compromises between these two objectives. Consider: a bicycle allows vastly more economical locomotion than walking or running - cycling allows a mass or weight to be transported a given distance for far lower metabolic work. This can be attributed to two factors: the rolling wheel produces a low demand for mechanical work; and the pedals and adjustable gearing allow the mechanical work and power demands to be met by muscles operating in an economical manner - with a high duty cycle (approximately 0.5) and at favorable stresses, strains and strain rates. Walking, running and flapping gaits cannot meet both of these demands for economical locomotion simultaneously; the two aspects - mechanical and muscle-physiological - have conflicting requirements. The conceptual Framework allows these conflicts, especially distinguishing between the muscle activation demands for mechanical work and power over a contraction, to be considered. Applications of the Framework to the scaling of posture, terrestrial gaits (hopping, walking, running) and flying gaits (flapping, bounding and flap-gliding) are reviewed.

P1.213 UYENO, TA*; CLUBB, BL; PEREZ, CP; CLARK, AJ; Valdosta State University, College of Charleston, College of Charleston; *tauyeno@valdosta.edu*

The biomechanics of looseness in hagfish skins

Most fishes have taut skins, preloaded in tension, that can efficiently transmit muscular force during locomotion, store and return elastic energy, and control body shape deformations. Hagfish, however, have very loose skins that do not function this way during swimming. There are two hypotheses for the adaptive function of loose skin: it may be required to form and manipulate body knots; it may also protect the body core from predatory bites. Here, we evaluate hagfish skin looseness as a defense against biting attacks by performing ASTM F1306 puncture resistance tests that account for different degrees of skin looseness. We measured the force, probe displacement, and energy required to puncture samples of loose and preloaded hagfish skins, skins of other fish, and samples of various manmade films. These data were then correlated with morphological descriptions (skin thickness, fiber type and orientation) of skins using standard paraffin histology and light microscopy. Preliminary results show that similar amounts of work are needed to puncture hagfish skins and other fish skins. In contrast to other fish skins, puncturing hagfish skin necessitates less force but the slack fit imposes low to negative levels of preloading that result in significantly longer penetration distances. This longer travel by the probe, or tooth, before actual work is done to puncture the skin, may result in reduced damage during an assault. The benefit of loose skin to hagfish may be twofold: Puncturing loose skin requires more energy than taut skin of similar penetration force and biting baggy skin requires teeth to travel further in order to puncture. This extra distance and time may allow the loosely attached body core to slip out of harm's way or even evade the attack altogether.

119.5 VAN ALSTYNE, KL*; PADILLA, DK; CHAN, M; YEE, AK; Western Washington University, Stony Brook University, Emory University; *kathy.vanalstyne@wwu.edu*

Do Dietary Chemical Signals Cue an Inducible Offense?

Chemical signals are increasingly recognized as triggers of defensive traits; however, less is known about their role in triggering changes in offensive traits. We explored the role of chemical signals in the induction of an herbivore offense, the morphology of radular teeth in *Lacuna* spp. *Lacuna* produce pointed teeth when consuming macroalgae and blunt teeth when consuming diatom epiphytes on eelgrasses. To determine whether *L. vincta* and *L. variegata* produce a default radular tooth type in the absence of chemical cues, we fed snails artificial diets amended with freeze-dried ground kelps, diatoms, eelgrass or Romaine lettuce. Snails fed diets containing lettuce, kelp, and eelgrass produced pointed teeth. Only snails fed diets with diatoms switched from pointed to blunt-shaped teeth, suggesting that pointed teeth are the default morphology and that a chemical cue originating from diatoms triggers the production of the alternate morphology. To confirm the latter, diatom epiphytes from eelgrass were extracted and partitioned into polar and non-polar fractions. *L. vincta* with pointed teeth were maintained in filtered seawater, fed Romaine lettuce, and exposed to polar or non-polar fractions. Non-polar fractions did not affect the number of snails producing blunt teeth. However, blunt teeth were produced more frequently in animals exposed to high concentrations of polar fractions, confirming that a waterborne polar chemical from diatoms can trigger the alternate morphology in *L. vincta*. Further work is needed to identify the signaling molecule and determine if it cues morphological changes in other gastropods.

120.7 VAN BREUGEL, F*; DICKINSON, M H; Caltech; *floris@caltech.edu*

Optimal search with unreliable and dangerous cues

Carbon dioxide is a broad signal of molecular decay, and it is almost universally attractive among insects in search of hosts, wildfires, flowers, decaying matter, communal nests, predators, and fruit. CO_2 is also, however, toxic at naturally occurring high concentrations. It is not clear how insects balance the information provided by this broad and dangerous signal with the information provided by odors that are more unique to their respective niches. This particular challenge is an example of a common dilemma that all animals face. To address this question, we studied how fruit flies balance the value of information provided by CO_2 and ethanol, both important odors produced during fermentation, their primary food source. We found that flies exhibit similar attractive responses towards CO_2 as they do towards ethanol, however, they invest twice as much time in searching near sources of ethanol. To understand what these differences in search times might mean in terms of their ecology, we simulated different virtual ecosystems and found that their strategy is optimized for scenarios where CO_2 and ethanol correspond to 30% and 70% chances of finding food, respectively. Our simulations extend beyond this particular case study by providing a plausible explanation for why experimental observations so often do not agree with predictions of optimal foraging theory and the marginal value theorem. Curiously, our result that flies find CO_2 attractive runs contrary to the majority of the scientific literature, which has suggested that flies find CO_2 aversive. In our experiments, we did find that flies occasionally do find CO_2 aversive, but only during times of low activity. This could be an adaptation to reduce the chances of falling prey to parasites or lethal concentrations of CO_2.

S9.3 VAN CLEVE, Jeremy; VAN CLEVE, Jeremy; University of Kentucky; *jvancleve@uky.edu*

Stags, hawks, and doves: Individual variation in helping in social evolution theory

In many species, animals can behave pro-socially by helping their neighbors survive or reproduce. Simple evolutionary models of these scenarios use the "prisoner's dilemma" from game theory and predict that helping strategies either invade and fix in a population or are entirely excluded by non-helping strategies. Classic presentations of Hamilton's rule produce this kind of prediction where populations evolve to be helpful if the fitness benefits of helping times genetic relatedness outweigh the fitness costs. However, individual-level variation in helping behaviors is common and likely to have fitness consequences, which requires studying helping in the context of two additional scenarios from game theory, the hawk-dove game and the stag-hunt game; behavioral variation can be maintained within populations in a hawk-dove game and between populations in a stag-hunt game. Recent theoretical analyses of the evolution of helping behaviors show that demographic, ecological, and behavioral factors can determine whether helping occurs in the context of a prisoner's dilemma, hawk-dove, or stag-hunt game. For example, ecological synergies in the production of benefits from helping determine whether the helping scenario starts with a prisoner's dilemma or a stag-hunt game at low levels of population structure. Increases in population structure (e.g., due to increases in relatedness) in turn can shift a prisoner's dilemma game to a hawk-dove game or a stag-hunt game to a mutualism game. Behavioral plasticity in the form of reciprocity can alter the fitness costs of helping and induce additional changes in the game structure towards more cooperative outcomes. By reviewing the sum of these effects, we can better understand how demographic, ecological, and behavioral factors shape selection for or against individual-level variation in helping behaviors.

P2.100 VAN KESTEREN, F*; WESTRICK, S.E; BOUTIN, S; HUMPHRIES, M; LANE, J; MCADAM, A; PALME, R; DANTZER, B; University of Michigan, Ann Arbor, MI, University of Alberta, Edmonton, AB, McGill University, Montreal, QC, University of Saskatchewan, Saskatoon, SK, University of Guelph, Guelph, ON, University of Veterinary Medicine, Vienna, Austria; *freyavankesteren@gmail.com*

Effects of maternal stress on oxidative signaling status of offspring in wild red squirrels

In animals that live in fluctuating environments, mothers may be able to prepare their offspring for the ecological conditions they are likely to experience at independence. In North American red squirrels in the Yukon, Canada, fluctuations in competition can alter the stress hormone levels of females that cause adaptive changes in the postnatal growth rates of their offspring. However, these changes in growth rates may come at some cost, as the allocation of limiting resources to one trait (growth) may have negative consequences for other traits requiring the same resource. One way in which such a trade-off is thought to occur is through oxidative stress, with increased growth leading to increased production of reactive oxygen radicals, which may cause cumulative oxidative damage. Here we examined how stress-mediated maternal effects affect offspring growth and oxidative signaling. We present data from a two-year manipulation of maternal stress levels in pregnant wild red squirrels and its effects on pup growth rates, oxidative damage to proteins in plasma and tissues, and antioxidant capacity in plasma and tissues.

29.6 VAN WASSENBERGH, S.*; DEVOS, P.; HERREL, A.; ADRIAENS, D.; Muséum National D'Histoire Naturelle, Paris, Ghent University, Ghent; *svanwassenbergh@mnhn.fr*

The trade-off between biting and singing performance in finches explained by biomechanical modelling

Field observations have shown that the species of Darwin's finches that specialized to feed on hard seeds have a decreased ability to conduct rapid changes in beak gape during singing. This limits their performance in producing dynamically complex songs. As songs of Darwin's finches are used in species recognition and mate choice, the observed trade-off between force and movement frequency of the beak may have had a direct influence on interspecies mating dynamics, probabilities of hybridization, and ultimately the process of speciation. However, it is unknown what causes this biomechanical trade-off. We analyzed this trade-off by dynamic, multi-body modelling based on a motion analysis of the beak of a species (Java finch) that closely resembles a Darwin's finch with a medium-sized beak, and an existing database of 3D morphology of the head of the Java finch and several Darwin's finches. Counter to our initial expectations, the model shows that increases in beak mass (to avoid beak fractures during forceful biting) have a negligible effect on the maximum attainable frequency of beak gape changes. However, when the beak opener system remains unmodified, the trade-off is caused by shifting of the gearing of the beak closer system to increase static bite force: such imbalance in gearing inevitably causes a pause between beak closing and the start of beak opening due to the twitch relaxation time of the beak closer muscles. Species with a head specialized to crack hard seed are thus mechanically limited to produce complex songs because of the negative effect of increases in moment arms and pennation angles of their beak-closer muscles on beak movement frequency.

P1.45 VAN WERT, JC*; MENSINGER, AF; University of California, Berkeley and Marine Biological Laboratory, Woods Hole, MA, University of Minnesota Duluth and Marine Biological Laboratory, Woods Hole, MA; *jcvanwert@berkeley.edu*

Jamming avoidance response in oyster toadfish, Opsanus tau

Vocalizing animals exploit certain behaviors to differentiate themselves among conspecifics. One mechanism is the jamming avoidance response (JAR), where individuals adjust the frequency of their signals relative to nearby conspecifics to avoid signal overlap. This behavior is utilized by animals that rely on signaling, such as weakly electric fish and bats. Male oyster toadfish, *Opsanus tau*, establish nests in mid spring and emit advertisement calls (boatwhistles) with distinct fundamental frequencies to attract females. The males appear to alternate calls to avoid temporal overlap, however, on occasion, the fundamental frequency of the callers are quite similar. The aim of this study was to investigate boatwhistle parameters among multiple males in a natural competitive environment. An *in situ* hydrophone continuously recorded vocalizations in Eel Pond, MA, from mid-June through late July 2016. Individual toadfish were distinguishable by waveform patterns, call duration, and amplitude. During a 36 hour calling period, the variation in fundamental frequency of an individual toadfish (e.g. 203 - 219 Hz) was closely correlated with water temperature change (22.5 - 24.0 °C) ($R^2 = 0.59$). In contrast, when conspecifics were also calling, toadfish with similar signals appeared to implement the JAR; when the fundamental frequency of one calling toadfish progressed toward the fundamental frequency of another, the individuals shifted their fundamental frequencies away from each other. This is the first time that this putative jamming avoidance behavior had been observed in the wild and demonstrates the complexity of these intraspecific interactions.

17.3 VANCE, J.; College of Charleston; *vancejt@cofc.edu*

Comparing Aerodynamic Efficiency of Flight Kinematics in the Honey Bee, Apis mellifera

Honey bee flight is metabolically expensive (>700 W kg^{-1}) in part due to their small wings, high wing-loading, and high wingbeat frequencies relative to other insects. Despite impressive aerodynamic reserves, bees' foraging behaviors maximize energetic efficiency and not net rate of energy intake, suggesting that selection may favor strategies that maximize efficiency across a broad range of aerodynamic output. Indeed, bees utilize patterns of angle-of-attack that maintain high lift-to-drag ratio, but they do not modulate this parameter as a strategy to maximize lift. To investigate whether bees utilize other kinematic strategies efficiently, a quasi-steady aerodynamic model evaluated the lift-specific power resulting from variation in wingbeat frequencies (*n*) and stroke amplitudes (Φ). Stereotyped kinematic patterns were generated from 3D kinematics of honey bee (*Apis mellifera*) hovering flight, and *n* and Φ were scaled beyond the variation in kinematic range observed in 2D and 3D studies. Bees predominant kinematic strategy, *n* = 220 and Φ ∈ {80:140}, incurred 21% greater lift-specific aerodynamic power at minimum lift production, but 22% lesser specific power at maximum lift production, than the kinematics Φ = 100 and *n* ∈ {175:306} (a strategy that produces a similar range in lift production by varying wingbeat frequency instead of stroke amplitude). Conversely, the kinematics Φ = 140 and *n* ∈ {125:220} incurs 35% less specific power at minimum lift and no difference at maximum lift. Thus, specific power could be reduced and efficiency improved if honey bees were capable of modulating wingbeat frequency, especially during flight requiring low lift production. However, such improvements would be minimized at elevated lift production, suggesting that the kinematic strategies observed in bees may be efficient for loaded flight.

78.5 VANDENBROOKS, JM*; LE VIN THUY, J; SHIEHZADEGAN, S; CAMACHO, A; TELEMECO, R; SMITH, C; ANGILLETTA, JR., MJ; Midwestern University, Arizona State University, Auburn Univeristy; *jvandenbrooks@midwestern.edu*

Can we differentiate between the effects of hypoxia and high temperature on animal behavior and physiology?

Oxygen availability and temperature are two of the most important environmental factors affecting all of animal life. However, the two are not independent of each other and may exert similar selective pressures on animals. Animals should be most susceptible to high temperatures and oxygen variation during times of high performance and during early developmental stages. Through a series of experiments on lizards and insects, we have begun to examine the interactive effect of oxygen and temperature on terrestrial animals exposed to hypoxia, high temperatures, and a combination of both during flight and embryonic development in the egg. The results of these experiments have been mixed in their support for the concept of an effect of oxygen during periods of thermal stress. We have shown that oxygen does limit thermal tolerance during embryonic development in lizards. However, while both hypoxia and high temperature have a detrimental effect on insect flight, there was no interactive effect between temperature and acute oxygen exposure or rearing oxygen. Additionally, while it has been shown before that extreme hypoxia does limit thermal tolerance in lizards, we have shown that ecologically relevant oxygen levels have no effect on voluntary maximum temperature. Lastly, we have been looking for a genetic correlation between flight performance during hypoxia and flight performance during high temperatures. Based on these experiments, there is limited support for the concept of oxygen limitation on thermal tolerance in terrestrial animals, however, more experiments under ecologically relevant conditions and behaviorally relevant activities need to be done.

P1.184 VANDER LINDEN, A*; HEDRICK, BP; KAMILAR, JM; DUMONT, ER; Univ. of Massachussetts, Amherst; *vanderlinden@bio.umass.edu*

Three-Dimensional Morphology of the Atlas Vertebra in Relation to Ecology in Primates, Rodents, and Relatives

Mammalian cervical vertebrae enable a variety of critical functions, including supporting the head, allowing flexion, extension, and rotation of the neck, influencing posture and locomotor behavior, housing the spinal cord, and anchoring axial muscles. The atlas (C1) in particular has a distinct functional role and exhibits pronounced variation among species. However, functional morphology of the cervical vertebrae has not been widely studied, and previous quantitative work on atlas shape in relation to ecology is focused only on haplorrhine primates. To investigate how atlas shape is influenced by the functional demands of supporting the head and flexing and extending the neck, we used 3D geometric morphometrics to quantify the shape of the atlas in 64 species of Euarchontogliran mammals. Our ecologically and taxonomically diverse sample includes primates, rodents, lagomorphs, tree shrews, and colugos. Data on body size, relative head size, posture, and locomotion were gathered from the literature and analyzed in relation to 3D atlas shape using phylogenetic generalized least squares (PGLS) regression. The first principal component axis of shape describes variation in the anterior-posterior length of the vertebra, while the second axis describes variation in the dorsal-ventral height and the convexity of the edge of the transverse process. When phylogeny was taken into account, shape variation along both PCs was not correlated with any size or behavioral variables. Our findings indicate that atlas vertebra shape may be influenced by phylogenetically inherited constraints at broad taxonomic scales in mammals.

S10.6 VARGAS, AO*; RUIZ-FLORES, M; NúñEZ-LEóN, D; SMITH-PAREDES, D; ACOSTA HOSPITALECHE, C; HAIDR, N; Universidad de Chile, Santiago, Museo de La Plata, La Plata, IBIOMAR CONICET, Puerto Madryn; *alexvargas@uchile.cl*

The role of embryonic muscular activity in the skeletal evolution of vertebrates

Skeletal evolution is better documented than any other system of the vertebrate body, including abundant data from the fossil record. Many studies show how the evolution of the musculoskeletal system has been channeled by adult function, but the evolutionary consequences of Embryonic Muscular Activity (EMA) are less discussed. EMA is ubiquitous across vertebrates, and is involved in normal development of functionally important structures. The mechanical forces of EMA can directly affect the shape of skeletal elements, their articulations, fusion patterns, and growth. Recent advances in the study of bony eminences at tendon insertion sites show common developmental mechanisms with sesamoid bones that involve EMA. This allows a renewed understanding of trends in the evolution of these structures. The effects of EMA are regulated by factors such as embryonic muscular arrangement (including secondary degeneration), and the progress of skeletal development, which determines plasticity upon mechanical forces. EMA can have its most significant effect during discrete periods or "decision points" of skeletal development. Regulation of EMA by these factors can affect the course of evolution, allowing the emergence of characters that may have not evolved otherwise, despite their high adaptive value after birth/hatching.

S4.7 VARPE, Øystein; University Centre in Svalbard; *oystein.varpe@unis.no*
Life history adaptations to seasonality
Seasonality is a central template in nature and an important selective force. Organisms display a range of adaptations to the abiotic and biotic processes that make up seasonal environments, leading to periodic time windows for their activities. Adaptations include the timing of key life history events such as reproduction, migrations, and diapause, as well as the plasticity of this timing in response to variability in environmental drivers. To understand the timing of one activity we must understand associated trade-offs and how natural selection shapes the full schedule of activities over the annual cycle - the annual routines. The trade-offs involve the fundamental properties of growth, energy storage, reproduction and survival. Timing of breeding and the associated birth-time dependent contributions to fitness are particularly important for understanding the evolution of annual routines. Seasonality in offspring value is common, but the parent and offspring perspectives on best timing can differ. I discuss these ultimate components of phenology and explain how fitness based models can help us predict optimal annual routines. I will further relate to a few selected questions: To what extent can seasonality and its impact on life history traits be a driver of speciation? What are the long term and carry-over effects of polyphenism generated by birth-time variability? How do we best approach and achieve a synthesis of proximate and ultimate perspectives on phenology? Finally, I also argue that high-latitude ecosystems can provide unique opportunities to answer these questions.

70.7 VAZ, D F B*; SUMMERS, A P; HILTON, E J; Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA, 23062, Friday Harbor Laboratories, University of Washington, Friday Harbor, WA 98250; *dbistonvaz@vims.edu*
Systematic Inferences of the Post-Cranial Skeleton of Batrachoiformes
The toadfishes (Batrachoidiformes) are a monophyletic group of bottom-dwelling fishes. One specialization of the skeleton of this group is an enlarged anterior precaudal vertebrae, with the third and fourth neural spines articulating tightly with modified pterygiophores. These derived pterygiophores support the dorsal spines and are historically called as "Basalia". The first epineural, which is enlarged and heavily ossified, also interacts with the bones of this region, articulating with the neural arch of the first vertebra. Although this overall arrangement has been proposed as a synapomorphy of Batrachoidiformes, but this seems a bold statement given the poor taxon sampling for this character. Furthermore, the interrelationships among the species of Batrachoidiformes and the relationship of this order to other percomorph fishes are not entirely resolved. To assess morphological variations in this skeletal complex, 42 species representing the four sub-families of Batrachoidiformes were examined using CT-scans and cleared and stained specimens. The aim was to identify characters that may be phylogenetic informative. We found that each sub-family has a distinct epineural arrangement and unique pterygiophore morphology. For example, in Halophryinae and Batrachoidinae, the pterygiophores that support the second and third spines articulate with the neural spine of the fourth vertebra. This condition of two pterygiophores articulating with a single neural spine is unique among Batrachoidiformes and most of other percomorph fishes. This condition, therefore, can be interpreted as synapomorphy grouping these two subfamilies.

P3.26 VAZIRI, GV*; ADELMAN, JS; VAZIRI, Grace; Iowa State University; *gvaziri@iastate.edu*
Sickness Behaviors in House Sparrow Flocks with Different Prevalences of Simulated Infection
Determining how an animal's social context alters the expression of sickness behaviors (e.g. lethargy and anorexia) will help us understand how pathogens impact individual health and spread within groups. Although several studies have shown that animals can suppress sickness behaviors when housed in larger groups, few have examined whether individuals alter sickness behaviors based upon the infection status of other group members. Here we tested for differences in sickness behaviors during simulated bacterial infection in captive house sparrows under two housing treatments: 1) all of the flock inoculated (6/6 birds), or 2) only half of a flock inoculated (3/6 birds). Inoculated birds were treated with lipopolysaccharide (LPS), a nonreplicating component of gram-negative bacterial cell walls, to induce sickness behaviors. We monitored lethargy using automated radio telemetry. We predicted that LPS-inoculated birds housed with a mixture of inoculated and healthy flockmates would exhibit less-pronounced lethargy (i.e. suppressed sickness behaviors) than birds housed with only LPS-inoculated flockmates. Contrary to these predictions, we observed that inoculated birds showed similar levels of lethargy regardless of the infection status of their flockmates. These results suggest that house sparrows do not modulate sickness behaviors in response to social contexts comprised of equal numbers of healthy and inoculated birds. However, further experiments will be necessary to determine if house sparrows modulate their sickness behaviors when a higher proportion of the social group remains healthy.

P1.269 VEJDANI, HR; BOERMA, DB; SWARTZ, SM; BREUER, KS*; Brown University ; *kbreuer@brown.edu*
Dynamical modeling of hovering in insects, hummingbirds, and bats
In hovering flight, which has evolved independently in insects, birds, and bats, animals can maintain a stable position in space while feeding on resources such as pollen and nectar. Here, we quantitatively model and simulate the hovering mechanisms observed in insects, hummingbirds and bats. We have developed a reduced-order dynamical model consisting of a rigid body (trunk), with three degrees of freedom (2 translational and 1 rotational), and two wings, each with two rotational degrees of freedom (elevation/depression and pronation/supination) and a folding/unfolding degree of freedom to modulate wingspan. The wings can be effectively massless (e.g., insect and hummingbird wings) or relatively massive (e.g., bat wings). We estimate aerodynamic forces using a quasi-steady blade element formulation. Based on extensive simulations, we outline a range of kinematic motion *without wing folding* that defines a necessary condition for hovering, and we validate this region with experimental data from insects and hummingbirds. We show that modulating pronation angle is critical for producing efficient hovering, and that this result is compatible with the recorded hummingbird wing motions. Our simulations also predict an optimal wingbeat frequency that produces a local minimum for power consumption. By mapping observations from nine hummingbird species, we show that their wingbeat frequency is consistently near the optimum flapping frequency. For bats, which possess relatively heavy articulated wings, we show that wing folding and unfolding is critical for permitting hovering and for maintaining a reasonable degree of power consumption. Comparisons with biological data show good agreement with our model predictions.

P1.241 VELÁZQUEZ, CCS*; BERG, O; MULLER, UK; TSUKIMURA, B; California State University Fresno; *umuller@csufresno.edu*

Swimming behavior of the shore crab larva Carcinus maenas: the kinematics and Particle Image Velocimetry

Studies on locomotion of walking and swimming of crustaceans have been conducted on adult crabs, and few have looked at the locomotion of crab larvae. There are many studies on adult walking and swimming patterns, muscle activity, and biotic factors (i.e. tidal environment: such as tidal currents and temperature). Although there are studies that looked at swimming mechanics of the crab larvae, these studies do not investigate the role of the larval swimming appendages, and do not elaborate on the swimming mechanics of the swimming appendages of the green shore crab (*Carcinus maenas*) larvae. The aim of this study was to examine the swimming locomotion of the crab larvae, in particular that of the green shore crab. High speed video recordings of swimming, and sinking of stage one green crab larvae were recorded to obtain swimming and sinking kinematics of the whole larva and its appendages. Moreover, we visualized the flow generated by swimming and tethered zoea using particle image velocimetry (PIV). Significant findings from this study include: swimming speed measurements that are twice as high as previously reported in green crab larvae, the first values of sinking speeds for green crab larvae, as well as a description of the maxilliped and natatory setae beating patterns during swimming.

120.4 VENABLE, CP*; LANGKILDE, TL; The Pennsylvania State University; *cpv111@psu.edu*

Choosing a Meal: Lizards Differentially Kill and Consume Native Versus Invasive Ants

Invasive species can pose novel threats to native species they encounter. The red imported fire ant, *Solenopsis invicta,* is a novel predator and toxic prey of the eastern fence lizard, *Sceloporus undulatus*. Lizards from sites with long histories of fire ant invasion innately avoid eating fire ants, but increase consumption of fire ants with repeated exposure. If these lizards can distinguish fire ants from native ants, this would facilitate avoidance of this toxic invader, or utilization of this newly abundant food resource. We simultaneously presented fence lizards with four fire ants and four non-toxic native ants (*Dorymyrmex bureni*) and determined the numbers of individuals consumed or crushed without consumption. Overall, the lizards killed more of the native ants than the invasive fire ants, and they ate more of the native ants than they crushed, but consumed and crushed fire ants at similar frequencies. Increased activity rates of the native ants do not completely explain the greater frequencies at which they were killed. We investigate the possibility that differential nutritional value is driving the differences in consumption. Lizards may kill fire ants primarily to remove them as a predatory threat, but kill native ants for food. Our results suggest that lizards may be able to actually distinguish between ant species, opening the possibility for species-specific adaptive responses.

101.3 VERHAGEN, IC*; GIENAPP, P; LAINE, VN; VAN OERS, K; MATEMAN, C; PIJL, AS; VISSER, ME; NIOO-KNAW; *i.verhagen@nioo.knaw.nl*

The Physiological Mechanism Underlying Timing of Reproduction in the Great Tit (Parus major)

Climate change shifted the timing of reproduction of the great tit (*Parus major*) but not as much as the phenology of their caterpillar food, leading to a phenological mismatch. This mismatch of offspring needs and caterpillar abundance has major fitness consequences and, as females laying earlier in spring now do better, there is strong natural selection for earlier laying. Predicting the response to this selection is difficult as lay date is a complex trait; the outcome of a physiological cascade, triggered by photoperiod and temperature. To gain insight in how natural selection can act on timing of reproduction we need to assess the genetic variation in these different components. To study this, we created two selection lines for early and late laying birds. For this, we used genomic estimated breeding values calculated from 500.000 SNPs 'trained' on the lay date of 2000 genotyped great tits from our long-term population in the Netherlands. During two years, selection line birds were pairwise housed in climate controlled aviaries and subjected to two contrasting environments, mimicking a cold or a warm year. We measured phenotypes at three levels: (key reproductive) gene expression, circulating hormone levels and lay date. We aim to determine differences between the selection lines in these three levels in response to artificial selection and in this way understand which component(s) of the physiological mechanism could be affected by natural selection. This knowledge about the genetic basis of the mechanism(s) underlying variation in timing of reproduction is crucial to predict whether the great tit will be able to adapt to their warming world.

39.5 VERHULST, S; University of Groningen, the Netherlands; *s.verhulst@rug.nl*

Telomeres and Life Histories; Where Are We Now and Where Are We Going?

Understanding the biological pathways causing life-history trade-offs is a challenge of major importance, because it concerns all life including humans. Telomere length potentially provides a unifying window on this problem, because many associations between telomere length and life history traits have been reported in recent years in a variety of species. In this talk I will provide a summarizing overview of current knowledge of associations between telomere length and the major life history components, reproduction and mortality. In this context, a distinction will be made between cross-sectional and longitudinal studies, showing how they differ in the information they provide. Our current knowledge on telomere length heritability will also be summarized. Lastly, I will briefly discuss to what extent the observed associations between life history traits and fitness components are likely to reflect a causal relationship. I will argue that, in the majority of cases, telomere length is probably an index of which the underlying physiological information remains to be identified, without having a direct effect on fitness components, while in exceptional cases telomere length is likely to be causally related to mortality.

P2.119 VERNASCO, B; RYDER, T.B.; HORTON, B.M.; MOORE, I.T.*; Virginia Tech, Smithsonian, Millersville University; *itmoore@vt.edu*

Individual Variation in Testosterone and Cooperative Behavior in a Neotropical Lekking Bird, the Wire-Tailed Manakin

Understanding the significance of individual variation in hormone levels and behavior is an important goal for behavioral endocrinologists as variation in behavior is often associated with reproductive success. Manakins are known for performing complex courtship displays at leks and these complex displays have evolved in association with strong reproductive skew, suggesting individual differences in courtship behavior exist. Furthermore, male wire-tailed manakins (*Pipra filicauda*) exhibit male-male cooperative displays and variation in this cooperative behavior has been found to be predictive of a male's probability of acquiring a territory and siring offspring. Our previous research has shown that territory-holding males have higher testosterone than floaters (i.e., non-territory-holding males), implying that testosterone plays a role in territory acquisition and maintenance. For the current study we quantified individual male courtship and cooperative behavior and subsequently collected a blood sample to measure testosterone concentrations. Our results show that males with a higher proportion of cooperative displays perform longer displays. However, males with high circulating testosterone engage in fewer cooperative display bouts suggesting that high levels of testosterone may interfere with effective cooperative behavior and result in shorter display bouts. These results suggest that individual differences in circulating testosterone levels play an important role in mediating individual variation in male reproductive behavior and potentially success. This research ultimately adds to our knowledge about the proximate mechanisms that mediate individual variation in both reproductive and cooperative behavior.

P3.179 VEZINA, F*; MILBERGUE, M; Universite du Quebec a Rimouski; *francois_vezina@uqar.ca*

Small birds can improve thermogenic capacity without changing their muscle size

Acclimatization to winter cold in small northern resident bird species is typically associated with increases in maximal shivering thermogenic capacity (summit metabolic rate, Msum) and physiological maintenance costs (basal metabolic rate, BMR) as well as with an enlargement of internal organs. It is believed that enlarging flight muscles in winter is a mechanism for improving cold endurance while larger supporting organs such as those used for energy acquisition are responsible for variation in maintenance costs. However, studies directly testing these assumptions are few and provide mixed support. We studied differences in body composition of captive black-capped chickadees (*Poecile Atricapillus*) acclimated for a month to -10°C or 26°C and investigated how the mass of individual organs were related to metabolic performance. As expected, cold acclimated birds had an Msum 20% higher than those kept at thermoneutrality. However pectoral muscles did not differ between temperature treatments. In contrast, BMR was 9% higher in cold acclimated birds and those also had digestive organs (liver, intestine, pancreas) up to 56% larger in the cold. Our preliminary results therefore suggest that temperature related changes in digestive organs might be related to maintenance costs variation in captive chickadee. They also suggest that these birds are able to improve thermogenic capacity without changing their muscle size.

P2.159 VILCHEZ, DE*; FIELD, KE; MARUSKA, KP; Louisiana State University; *dvilch1@lsu.edu*

Differential Expression of Putative Pheromone-detecting Cells and Receptors in the Olfactory Epithelium of an African Cichlid Fish

Across taxa, chemical signals convey crucial information, such as fitness, social status, and reproductive state. It is well established that several fish species use chemosensory signaling during reproduction, with individuals possessing mechanisms to detect sexually-relevant olfactory signals at a reproductive advantage. In fishes, odorants are detected by one of three main olfactory receptor neuron (ORN) types located in the olfactory epithelium. Crypt cells, an ORN unique to fishes, is hypothesized to function in pheromone detection, and one family of recently described receptors known as vomeronasal-like type 1 receptors, or V1Rs, are hypothesized to bind these sexually-relevant compounds. Here, we tested whether social status and/or reproductive state might influence crypt cell and V1R expression in the olfactory epithelium of highly social African cichlid, *Astatotilapia burtoni*. Males exist as either dominant (reproductively active) or subordinate (reproductively suppressed), and females cycle between gravid (reproductively receptive) and mouthbrooding parental care states. Using the crypt cell marker s100, we found that gravid, ready to spawn females had more crypt cells in their olfactory epithelium compared to reproductively suppressed brooding females. Similarly, in situ hybridization for one of the six V1Rs in fishes, *V1R4*, revealed different levels of expression in animals of different reproductive and social status. Since reproduction can be considered the most important event in any animal's life, gaining insight into the cellular and molecular mechanisms that mediate the detection of sexually relevant stimuli is important in understanding how reproduction is coordinated

S4.10 VISSER, M.E.*; VERHAGEN, I.C.; RAMAKERS, J.; LAINE, V.N.; GIENAPP, P.; Netherlands Institute of Ecology (NIOO-KNAW); *m.visser@nioo.knaw.nl*

The evolution of mechanisms underlying seasonal timing of avian reproduction

Species need to time their reproduction and growth such that these activities match the annual period of favourable conditions, often set by the seasonal timing of other species. Climate change has led to unequal shifts in timing among species at different trophic levels, leading to a mismatch between the time of the need for, and the availability of, resources. A key question is how fast species can adapt to climate change. I will address this question using our work on a simplified food chain of oaks - winter moths - great tits & pied flycatchers, combining field work, field experiments and experiments in captivity. In this system, we measure how natural selection on seasonal timing has changed over the course of our long term study (1955-present). We link this with work on the genetic variation in the physiological mechanisms underlying seasonal timing as this is what is needed for evolutionary adaptation. I will present some of our ongoing work on artificial selection for early and late egg-laying great tits using genomic selection. With these artificially selected birds, we study which components of the underlying mechanism can be altered by selection, and we can release these birds into the wild to study their reproductive success. This way, we aim to explore whether species can adapt fast enough to climate change.

127.1 VITOUSEK, MN*; TAFF, CC; ZIMMER, CG; ARDIA, DR; SALZMAN, TC; WINKLER, DW; CORNELL UNIVERSITY, FRANKLIN AND MARSHALL COLLEGE; *mnv6@cornell.edu*

Do Brief, Acute Stressors Have Lasting Effects on Phenotype?

Glucocorticoid hormones play an essential role in responding to stressors, as well as in mediating important behavioral and physiological traits. Moderate to long-term elevations in circulating glucocorticoids, like those seen in the context of chronic stress, are known to impair reproduction. However, it is not clear whether brief acute increases in glucocorticoids - like those observed during the course of a normal stress response - also influence reproductive behavior or success. A multi-year analysis in tree swallows *(Tachycineta bicolor)* indicates that variation in the magnitude of the glucocorticoid stress response strongly predicts reproductive success: females that mount stronger responses to a standardized restraint stressor during incubation later fledge fewer and smaller young. To assess whether these links are causal we experimentally induced a brief, acute glucocorticoid response of varying magnitude in free-living tree swallows, and measured the immediate and longer-term effects on parental behavior and physiology, as well as nestling phenotype and survival. The results of these studies have implications for understanding the evolution and regulation of the stress response, and for determining whether brief exposure to passing stressors can have lasting impacts on phenotype and fitness.

P2.264 VOISINET, MP*; VASQUEZ, MC; ELOWE, C; CROCKER, DE; TOMANEK, L; Cal Poly San Luis Obispo, CA, Sonoma State University, CA; *mpvoisin@calpoly.edu*

Proteomic response of elephant seal pups, Mirounga angustirostris, to prolonged fasting.

Northern elephant seals (*Mirounga angustirostris*) have several key physiological adaptations allowing them to develop from a terrestrial nursing pup to a juvenile able to dive and forage independently in the water. During the approximately 8-week time period between the weaning of the pup and their departure to sea, juvenile seals rely solely on the energy reserves they gained during nursing for all caloric and water demands. While adult elephant seals fast during molting, mating, and lactation, pups fast while undergoing a major transition from a terrestrial to an aquatic lifestyle. The purpose of this study was to understand the fasting-induced adaptive responses of pre- and post-weaning *M. angustirostris* pups using a proteomics approach. We collected tissue from skeletal muscle and the inner and outer adipose layers of both pre- and post- weaning pups (n = 20). After performing first and second dimension gel electrophoresis, we analyzed the samples using mass-spectrometry-based proteomics. In the post-weaning time-point, we identified significant decreases in proteins related to glycolytic metabolism, possibly indicating a shift from a carbohydrate to a lipid based metabolism in muscle. There were also increases in cytoskeletal proteins, as well as oxygen-binding proteins that aid in the development of diving ability in post-weaning pups. We found both significant increases and decreases in the abundance of proteins related to oxidative stress, highlighting how the unique stressors of each weaning phase effects the pup's physiology differently. This study will provide important information about the adaptive capacity of marine mammals at a critical developmental stage.

145.6 VOLTZOW, J*; CRONIN, C; SMIEJA, J; Univ. of Scranton, Gonzaga Univ.; *janice.voltzow@scranton.edu*

Trends in Institutional Policies for Work/Life Balance at Undergraduate Institutions

One of the greatest challenges for faculty is balancing a meaningful home life with the requirements of teaching, scholarship, and service. Policies concerning parental leave, pausing the tenure clock, and eldercare vary greatly from institution to institution and can be confusing or contradictory. We gathered information about these policies as of October 2015 from institutions participating in our NSF ADVANCE grant, which created a network of female STEM faculty at undergraduate institutions, and compared them to those reported in Taylor & Dilks (2015 J. Div. Higher Ed.), who studied all institutions that received NSF ADVANCE grants before 2012. Compared to this larger sample, our institutions are smaller and a larger proportion are private. Parental leave policies in our institutions varied widely. Almost one-third offer little more than the minimum leave without pay required by the Family and Medical Leave Act of 1993 (FMLA), while almost one-fourth provide a teaching release of one semester. The same pattern holds for a tenure clock extension for the birth mother. Almost one-third of our institutions have no policy but almost 40% provide an automatic one-year extension upon request. None of our institutions and few of the larger sample provide anything beyond the provisions of FMLA for eldercare. These comparative data could permit faculty to negotiate for enhanced benefits at their home institutions.

P2.206 VOLTZOW, J*; IYENGAR, EV; Univ. of Scranton, Muhlenberg College; *janice.voltzow@scranton.edu*

A tale of two snails: Commensalism, parasitism, or "friends with benefits"?

Many marine organisms live in close association with members of other species. These relationships range from parasitism to commensalism to mutualism. Gastropods in the genus *Calliostoma* use their feet to wipe the surfaces of their shells, which may influence the settlement and sustained attachment of fouling organisms. Surprisingly, individuals of *Calliostoma ligatum* living in the San Juan Islands, Washington, are frequently fouled by one to several individuals of the sedentary, suspension-feeding gastropod *Crepidula adunca,* while individuals of other local species within the genus and other co-occurring trochids, including *Margarites pupillus*, are rarely fouled. Videos show that the foot of the host passes directly over the epibionts as it wipes the shell without disturbing even very small (< 2 mm) individuals. The majority of epibionts occur on the left side of the body whorl of the host, with the second-most common location in the middle of the posterior portion of the body whorl. Videos of individual *Calliostoma ligatum* in a recirculating flow tank show that regardless of orientation with respect to flow, water moves up the downstream side of the turban-shaped shell. Thus the preferred locations of the epibionts are regions that would receive enhanced flow. Photographic surveys of marked hosts in the laboratory indicate that although larger (> 5 mm long) individuals of *Crepidula adunca* do not move, smaller individuals may change their positions on the host or move from one host to another. These observations indicate that this association benefits the epibiont but do not suggest any potential benefits to the host.

110.3 VON DASSOW, YJ*; VON DASSOW, M; Duke University Marine Lab; *yasmin.vondassow@gmail.com*
Drying But Not Dying: How Do Intertidal Slug Embryos Survive Environmental Fluctuations?
Development is a complex, seemingly fragile process, but embryos often tolerate large environmental fluctuations. For example, embryos of the sea slug *Haminoea vesicula* are laid on submerged substrata but can survive stranding out of water at low tide, despite being protected only by thin, gelatinous, ribbon-shaped egg masses. Previous work showed that *H. vesicula* embryos survive for days in egg ribbons that have lost 80% mass through dehydration, even when embryos are damaged to the point of dissociation. We examined two aspects of this remarkable ability. First, we hypothesized that stranded embryos would not survive to hatching. We simulated low tide by exposing egg ribbons to air and sun for 1 hr. Even in ribbons that lost 70% mass by dehydration, embryos still developed and hatched as veligers, many of which were malformed but some of which could still feed. Second, we hypothesized that three different structures — egg ribbon gel, egg envelopes, or cell membranes — could potentially protect embryos from increased salinity due to evaporation, by acting as diffusion barriers to water and salt. Fluorescein spread quickly through egg ribbon gel, indicating high permeability, so the gel likely does not prevent embryos from experiencing large salinity changes during drying. Embryos removed from the gel and put in hypersaline seawater shrank within 3 minutes, suggesting that neither envelopes nor cell membranes are significant permeability barriers on the timescale of exposure. Embryo volume remained greatly reduced over ≥ 1 hr, so cell volume regulation is insufficient to protect embryos from water loss. Thus, to survive stranding, *H. vesicula* embryos must tolerate large changes in the concentration of intracellular compounds, and may require regenerative abilities.

P2.181 VOSS, MA*; TEALE, S; SEMLER, E; Syracuse University, SUNY College of Environmental Science and Forestry; *mavoss@syr.edu*
To catch a thief: Do bird parasites unlock the chemical code of metabolic status to identify potential hosts?
Approximately 50 years ago a muscid fly native to mainland South America, *Philornis downsi*, was accidentally introduced to the Galapagos Islands. In the larval stage, *P. downsi* is a blood feeding parasite of newly hatched birds. In its native range the fly parasitizes a broad mix of passerines species. *P. downsi* is now present on 13 of the 15 Galapagos Islands and has been found on the newly hatched chicks of 16 endemic bird species. Parasitism has increased markedly over the past 20 years and several species, such as the Mangrove Finch (*Camarhynchus heliobates*), are in now in significant decline. Adult *P. downsi* appear to be attracted to host odors released near the time of neonate hatch. Oviposition by female flies is precisely timed so that first instar larvae colonize the nasal cavities of newly hatched chicks. Nestling mortality can be as high as 100% in some host species. We are investigating volatile compounds from passerine nests as potential host identification cues for *P. downsi*. We have sampled volatiles from the eggs, uropygial gland secretions, meconium, and active nests of several passerine families. Recent EAG experiments show that the uropygial secretions of some species contain compounds that elicit neurophysiological responses in *P. downsi* antennae. Many of these compounds are common products of adult passerine and embryonic lipid metabolism. We are exploring the possibility that the concentration of metabolic volatiles increases with the pip of the first egg 24 hours before hatch and peaks as multiple chicks emerge from eggs. The increase in volatile concentration may be the chemical signal used by gravid *P. downsi* to reliably identify nests a few hours before hatch and time oviposition to optimize larval growth.

72.7 WADA, H.*; FINGER JR., J.W.; Auburn University; *haruka@auburn.edu*
A potential link between organismal adrenocortical responses and cellular heat shock responses
Virtually all organisms face environmental stressors; how they cope with them via eliciting necessary physiological and behavioral changes holds the key to species' survival and reproduction. Despite the importance of understanding these stress responses, integrative stress responses, particularly the relationships among stress responses at organismal and cellular levels, are not well understood. Here we focus on the link between organismal adrenocortical responses involving glucocorticoids and cellular heat shock responses. They are several parallels between the two; both stress responses change with season and age and play an important role in development and reproduction. More importantly, heat shock proteins are involved in every step of glucocorticoid receptor assembly and function. We discuss supporting and opposing evidence of the link between the two stress responses in *in vivo* and *in vitro* studies and propose reactive oxygen species as a potential mediator between adrenocortical and heat shock responses.

74.1 WAGNER, JT*; SINGH, PP; BRUNET, A; MINX, P; WARREN, W; PODRABSKY, JE; WAGNER, Josiah; Portland State University, Stanford University, Washington University; *josw@pdx.edu*
Positive selection and gene family changes in a fish extremophile
In order to complete their life cycles, all metazoans require oxygen and water. However, environments are not always forgiving when it comes to constantly providing these basic needs for life. Many metazoans that thrive in highly stressful or variable environments cope by arresting development in and entering into states of metabolic depression and developmental arrest, such as diapause. The annual killifish *Austrofundulus limnaeus* (Meyers) is possibly the most well described example of vertebrate embryonic diapause, and its embryos have been shown to tolerate extremes in oxygen, salinity, Ultraviolet-C radiation, and water availability. Large-scale genetic analyses have only been recently possible in *A. limnaeus* with the release of its annotated genome. In this work, we test for positive selection in the *A. limnaeus* lineage using the PAML software package and include 12 other teleost species as background branches. Additionally, we look for changes within gene families among these taxa using CAFE software, which models gene birth and loss along the phylogenetic tree to assess significance of observed gene family size differences. Our results suggest that there maybe several amino acid sites under selection in the *A. limnaeus* lineage. Additionally, several gene families have expanded or contracted in species, including *A. limnaeus*, that are known to be stress tolerant. These results suggest several genes of interest that my be important for extreme stress tolerance and may be ideal targets for future functional studies.

P3.261 WAGNER, JM*; HARRISON, JF; Arizona State University; *jmwagne7@asu.edu*
Hypermetric Scaling of Spiracles in Some Scarab Beetles
One hypothesis for why insects are smaller than vertebrates is that possessing a blind-ended tracheal respiratory system results in physiological challenges in oxygen delivery for larger insects. If this is the case, we might expect to see that larger insects have relatively larger gas transport structures. To test this possibility, we performed the first inter-specific study of the scaling of spiracle size, using scarab beetles, the insect clade with the most massive species. We took full body micro-CT scans of 17 individuals of 10 species. We measured cross sectional area of the spiracles' opening, as well as the depth from the opening to the valve structure behind the spiracles' atrium, and assessed the scaling of spiracular area, diffusive capacity (area/depth), and advective capacity (area^2/depth). Data were log-transformed and slopes corrected for phylogenetic relationships among the species. Spiracles in the anterior portion of the animal, especially the large mesothoracic spiracle, showed hypermetric scaling, indicating that larger beetles have spiracles with a relatively higher diffusive and advective capacity (less resistance) compared to smaller ones, while the small posterior abdominal spiracles showed isometric scaling. For the metathoracic and first two abdominal spiracles, the pattern differed among subfamilies, with hypermetric scaling in Cetoniinae as compared to isometry in Dynastinae. These findings demonstrate that for the largest spiracles responsible for most gas exchange, some larger beetles have relatively larger spiracles, supporting a growing body of evidence that, unlike vertebrates, larger insects may selectively increase the relative size of specific respiratory structures to support their greater gas exchange needs.

52.4 WAINWRIGHT, D.K.*; FISH, F.E.; LAUDER, G.V.; INGERSOLL, S.; WILLIAMS, T.M.; ST. LEGER, J.; Harvard University, West Chester University, University of California, Santa Cruz, SeaWorld, San Diego; *dylanwainwright@fas.harvard.edu*
How smooth is a dolphin?
Dolphin skin along the trunk of the body has a ridged texture that has been hypothesized to interact beneficially with the water during swimming. However, previous studies are limited in their ability to quantify surface roughness and three-dimensional surface structure. We use a molding technique to capture the skin texture of 5 live bottlenose dolphins (*Tursiops truncatus*) at various locations around the body, which we then analyze and compare to previous measurements of dolphin skin, as well as to other pelagic sharks and bony fishes capable of high-speed swimming. Analysis using a gel-based contact profilometry procedure allows us to reconstruct surface topography on 1.4 cm by 2.2 cm sized patches of skin, and to calculate metrics of surface roughness. We find that ridges do exist on the surface of the bottlenose dolphin, but these ridges are only 6 microns in height, compared to the 24 microns measured previously. Our measurements of ridge period have a range of 180-780 microns, which includes the range measured previously (560-710 microns). Bottlenose dolphin skin has an average roughness of 2.6 microns across 5 sites along the body. As a comparison, dolphins are rougher than extruded aluminum (0.06 microns), and about equal to trout covered in mucus (2.6 microns). Dolphins are smoother than many other large pelagic predators: bigeye tuna have roughness values of about 11 microns, marlin range from 12.5 to 68 microns, and pelagic sharks have values between 5 to 15 microns. Dolphin body skin is thus extremely smooth. The range of roughness values for different species suggests there are multiple solutions to the design of surface textures that could reduce drag in pelagic swimmers.

P1.85 WALTERS, L*; MAKRIS, P; ANDERSON, L; QUINTANA-ASCENCIO, P; SACKS, P; Univ. of Central Florida; *linda.walters@ucf.edu*
Where have all the Oysters Gone? Multiple Stressors Impacting Estuarine Oysters
Previously we documented that recreational boat wakes negatively impact intertidal reefs of the eastern oyster *Crassostrea virginica* in shallow estuaries by eroding sediment away from the buried bases of clusters, thus promoting dislodgement with the next large wake pushing loose clusters above the high tide line. Here, we provide data on the role that the brown tide microalga *Aureoumbra lagunensis* plays when present in these same shallow estuaries. *A. lagunensis* reached bloom concentrations in the Indian River Lagoon in summer 2012, spring 2013 and, currently with a start in February 2016. *C. virginica* recruitment was negatively impacted by brown tide (but some recruitment did occur), while their primary competitors (barnacles) were not negatively impacted, giving the latter a potential advantage. In replicated, laboratory flume trials, settlement of oyster larvae was negatively impacted by algal concentration and salinity. After a short exposure (1 week) of oyster spat (juveniles) to a range of concentrations of *A. lagunensis* (0 - 1 million cells/ml) and subsequent monitoring for 1 month in lagoon water with no brown tide, we found a significant reduction in survival by individuals exposed to bloom concentrations of brown tide. This decline in survival was from 95% to 85%, thereby suggesting the importance of *A. lagunensis* in altering shallow estuary ecosystems, but also the resiliency of the eastern oyster *C. virginica* to this stressor.

9.4 WALTON, AR*; DOLEZAL, AG; TOTH, AL; WALTON, Alexan; Iowa State University; *awalton@iastate.edu*
Larval and adult pollen diet affects a honey bee worker's response to the queen
The importance of diet and nutrition on morphology, physiology and behavior has been well studied in honey bees, especially in the context of division of labor. The task of queen tending (feeding, examining, and grooming the queen) is integral to the health of honey bee colony and natural variation in response to the queen exists amongst the workers of a honey bee colony. This variation in response may lead to an increased of division of labor (specific individuals are more likely to respond to, and thus care for, the queen). These types of variations in response to stimuli can benefit the entire colony. Is it possible that a worker's pollen consumption (her source of protein) can affect her likeliness to care for the queen? We found evidence that a worker's diet as an adult (with or without pollen) affects her responsiveness to queen pheromone. Bees that had pollen-deficient diets displayed an increased response to queen pheromone. Additionally, we manipulated the diversity of pollen that larval honey bees had access to during development, and found that the nutritional environment of worker larvae can have long term effects on her response to queen pheromone as an adult. Honey bee workers are sterile, but have some reproductive potential, and can lay eggs of their own if the queen dies. Differences in pollen diets may lead to differences in reproductive potential (by way of contributing to ovarian development) and may lead to these differences in response to the dominant reproductive individual. Because there is likely variation in how much pollen workers of the same hive have access to and ingest, this variation in diet may have the effect of contributing to the division of labor of the colony. Variation is important to maintain a division of labor, so this variation in pollen-diet/queen-response likely has beneficial properties for the entire colony.

P1.49 WANAMAKER, SM*; SCHWABL, H; Washington State University ; *sarah.wanamaker@wsu.edu*

Exploring the Use of Olfaction in House Sparrow (Passer domestics) Behavior

Chemosignals are an important means of communication between individuals across taxa, from bacteria to mammals. Nonetheless, a traditional belief that birds have little sense of smell has left the field of avian olfaction largely ignored. Yet there is growing evidence that olfaction is used by many avian species in various contexts. Here, we explore the role of odors in songbird behavior using a captive house sparrow (*Passer domesticus*) model. Behavioral trials tested subjects' responses to 1) predator odor and 2) male and female conspecific odors. During behavioral trials, female sparrows were provided two nest boxes each containing either a treatment or control odor. To test whether females respond to predator odors, the nest boxes contained used or unused rat bedding. We predicted that individuals would detect and avoid the predator odor by spending more time at the predator-free nest box. To test whether intraspecific odor acts as a sexual signal, preen oil from either male or female sparrows was placed in each nest box; previous research suggests preen oil may be used as a chemosignal, but few studies have tested this. We predicted that as females enter breeding condition, motivation to find a mate would increase and females would therefore spend more time investigating the male-scented nest box. Individual response to these odors was measured using motion detectors to record movements in or around next boxes, and these data were used to deduce odor preference. We found that female house sparrows avoided the treatment nest box containing used rat bedding, supporting our hypothesis that house sparrows use olfactory cues to detect and avoid predators. However, there was no significant difference in the amount of time spent with the male or female odor. Thus, our hypothesis was not supported. It is possible that male odor alone did not pique female interest, but is one of multiple cues used in mate choice.

63.3 WANG, Y; YANG, X; CHEN, Y; KENALEY, CP; LIU, H; GUAN, J; WAINWRIGHT, DK; WOOD, RJ; WEN, L*; Beihang University, Harvard University, Harvard University; *liwen@buaa.edu.cn*

A Bio-robotic Remora (Echeneis naucrates) Adhesive Disc: Design, Fabrication and Function

Remoras have the remarkable ability to hitchhike on an array of host organisms by using an adhesive disc located dorsally on their head. By actively pitching rows of lamellae in the open center of the suction disc, remoras push lamellae against or away from the host's surface, thereby tuning attachment to different hosts. We designed and fabricated an at-scale, multi-material bio-robotic remora disc (12.7 cm long and 7.2 cm wide) that contains a soft lip at the periphery, consecutive rows of lamellae with composite materials, and rigid spinules on top of the lamellae. Fluidic elastomer soft actuators were designed to control the lamellae pitching motion. We investigated the influence of the lamellae pitch angle and surface roughness on adhesive ability (quantified by chamber pressure, pull-off tenacity and frictional force) of the biomimetic remora disc in an aquatic environment. The interfacial contact mode between the lamellae and the smooth glass substrate was visualized. With very small preloads, the biomimetic robotic remora disc can attach to surfaces of different roughness, and generate considerable frictional force (>23N) and pull-off strength (>200N). We also found that by controlling the lamellae pitch angle, the lamellae soft-tissue and the rigid spinules could work together to achieve tunable, anisotropic friction while maintaining a seal on the surface. Finally, this bio-robotic remora disc was incorporated to an underwater robotic vehicle to demonstrate robust hitchhiking on different surfaces.

P2.89 WANG, VR; SAITO, A*; SUZUKI, Y; Wellesley College; *vwang2@wellesley.edu*

Transcriptional regulation of ecdysteroid biosynthesis in the tobacco hornworm, Manduca sexta

Metamorphosis is characterized by dramatic morphological changes during the life cycle of an organism. In many insects, metamorphosis is triggered by a size-dependent mechanism, which involves the interaction of prothoracicotropic hormone (PTTH), ecdysone, and juvenile hormone (JH). However, how these endocrine regulators interact to influence the transcriptional regulation of hormone production remains unclear. The POU (Pit-Oct-Unc) factor Ventral veins lacking (Vvl) has been shown to play an important role in the transcriptional regulation of insect metamorphosis. Thus, the expressions of *vvl* and cytochrome P450 genes in the prothoracic glands of *Manduca sexta* were evaluated in hormone treated and starved animals. Our findings suggest that nutrition and hormones affect the transcription of *vvl* and the ecdysteroid biosynthesis genes in *Manduca*. We discuss how these gene expression profiles relate to known body size thresholds in *Manduca*.

P2.228 WANG, AZ*; HUSAK, JF; Univ. of St. Thomas; *andrew.wang@stthomas.edu*

Leptin as a potential mediator of trade-offs among performance, reproduction, and immune function in green anole lizards

Life history trade-offs result from allocation of limited energetic resources to particular traits, restricting those same resources from different traits. This differential allocation of resources is dependent on the conditions the organism is living in, and promotes traits that suit the organism's best needs between survival and reproduction. In previous studies, green anole lizards were shown to have dramatic decreases in fat stores, immune function, and reproduction when physically trained, and this was exacerbated by diet restriction. We gave supplemental leptin to green anole lizards in an attempt to mitigate the negative effects of shifting resource allocation due to a combination of exercise training and diet manipulation. We hypothesized that supplemental leptin would 'rescue' energy allocation to reproduction and immunity due to the artificial signal that there is more energetic resources than there actually is available. Lizards were assigned to one of six treatment combinations across three factors (diet restricted or not, trained or not, and leptin or saline control) over the course of nine weeks. To measure immune function, we measured the swelling response to phytohemagglutinin. Leptin supplementation did not override the stress of injections to 'rescue' reproduction, but leptin did increase immune response across both diet treatments. Endurance and growth were unaffected by leptin, though the stress of injections seemed to decrease performance enhancement. Diet restriction decreased growth in both sexes, with or without leptin supplementation. Our results highlight the complex nature of how trade-offs are mediated, and suggest differential and interactive roles for leptin, corticosterone, and pathways associated with the exercise response.

P3.58 WANG, W*; LUTTRELL, S; SWALLA, BJ; University of Washington, Seattle; *weslew@uw.edu*

Molecular Analysis of Neural Regeneration in Ptychodera flava

Regeneration is a well-documented ability that has high applications to modern medicine. Many marine model systems have been utilized to better understand the molecular processes that underlay this ability. *Ptychodera flava* exhibits exceptional abilities in regenerating entire parts of its central nervous system. We examined the expression of 7 developmental genes—transcription factor genes *Pax6, Six3, Dlx, Msx-2,* and *POU* and signaling genes *Chordin* and *Frizzled*—during different days of regeneration. Whole mount *in situ* hybridizations of *P. flava* from 2 to 7 days of regeneration were utilized to map the expression of genes and times at which they are expressed. *In situ* hybridization data revealed the expression of neural genes to follow a slightly varied anterior-posterior patterning as seen in developing chordates and direct developing hemichordates. Further studies are necessary to tell whether variation between expression in *Saccoglossus kowalevskii* and *P. flava* is due to variation in the mechanisms controlling gene networks during hemichordate development and regeneration.

92.4 WANG, ZY*; RAGSDALE, CW; University of Chicago; *zyw@uchicago.edu*

Maternal behavior and death in the octopus

Perhaps the most important event in an organism's life is reproduction, a complex behavioral process tightly controlled by signaling between the nervous system and the reproductive organs. The metabolic and fitness costs of reproduction are extreme for semelparous individuals, such as octopuses, who produce offspring only once before dying. Octopuses show striking changes in behavior after reproduction: while brooding their clutches, female octopuses will first stop feeding and then undergo a rapid senescent decline leading to death. This sequence of events, including death, is under central hormonal control. Ablation of paired neurosecretory centers, the optic glands, leads to a complete reversal of all maternal behaviors: females cease brood care, resume normal feeding behaviors, and experience a greatly increased lifespan (Wodinsky, 1977). Despite the important roles the optic glands play throughout the octopus's life, they remain understudied using modern techniques. To explore the molecular bases of optic gland hormone signaling, we carried out Next-Generation RNA sequencing on optic glands of *Octopus bimaculoides* females at each of the three behavioral epochs of brooding: feeding, fasting, and deterioration. These transcriptomes were compared with those of central brain, optic lobe, viscera, posterior salivary gland and the ovaries. We identified cohorts of genes that are differentially expressed over the behavioral epochs, suggesting an extensive regulatory network dedicated to female reproductive behaviors such as brooding, fasting, and senescence.

7.7 WARBURTON, EM*; KHOKHLOVA, IS; KIEFER, D; KRASNOV, BR; Ben Gurion University of the Negev; *warburte@post.bgu.ac.il*

Morphological Asymmetry and Habitat Quality: Using Fleas and Their Rodent Hosts as a Novel Experimental System

Morphological asymmetry is widely used to measure developmental instability and higher levels of asymmetry often correlate with decreased mating success, increased inbreeding, increased stress, and decreased habitat quality. Links between asymmetry and environmental quality provide a novel context for host-parasite relationships because habitat a parasite experiences consists of host immunological and physiological processes. Parasites colonizing novel host species could therefore exhibit increased asymmetry due to decreased habitat quality. Our goal was to determine if asymmetry in fleas *Xenopsylla ramesis* and *Parapulex chephrenis* increased when their mothers were reared on species of rodents differing in their relatedness to the fleas' principal host. We found significant asymmetry in femurs and tibiae of *X. ramesis* but asymmetry was not affected by host relatedness. However, tibae of *P. chephrenis* exhibited significant asymmetry and asymmetry was highest in fleas whose mothers were reared on hosts that were distantly related to the principal host. These results indicate that host species and, in turn, habitat quality significantly impacted asymmetry in *P. chephrenis*, a host specialist, but not *X. ramesis*, a more generalist flea. Therefore, fleas parasitizing multiple species may be better at compensating for developmental instability than host specialists when utilizing a novel host species. This suggests that host-switching events in host specialists may be constrained by the relatedness of the different host species in question.

P2.215 WARBURTON, EM*; KHOKHLOVA, IS; KIEFER, D; KRASNOV, BR; Ben Gurion University of the Negev; *warburte@post.bgu.ac.il*

Effects of Parasitism on Host Reproductive Investment in a Rodent—Flea System

Individuals may alter their reproductive investment depending on the type of environment they encounter. Females experiencing stressful conditions might opt to alter sex ratios of litters or invest more into current rather than future reproduction. In the context of parasitism, these effects could manifest as parasitized mothers producing more female offspring, as in the Trivers-Willard Hypothesis, or producing offspring that reach maturity quickly. Our goal was to determine if infestation by fleas *Xenopsylla ramesis* and *Parapulex chephrenis* altered sex ratio or amount litter quality in two rodents: *Meriones crassus* and *Acomys caharinus*. Further, flea infestations included characteristic fleas, non-characteristic fleas, and a mix of the two to determine if number and type of fleas significantly altered host reproductive investment. We found no effect of infestation on sex ratio for either rodent species and no effect of infestation on litter mass, litter size, or pup mass gain in *A. caharinus*. However, treatment did have an effect on litter mass in *M. crassus*. Further, a significant interaction between treatment and litter size on pup mass gain in *M. crassus* indicated that small, parasitized litters gain the most mass. These results suggest that, at least in *M. crassus*, infested mothers produce offspring that mature more quickly but do not alter sex ratio of their litters in response to infestation. Thus, mothers may invest more in current reproduction when subjected to the stresses of parasitism.

P1.55 WARD, MV*; GRAY, BL; WILLIAMS, K; Ohio University; *mw352308@ohio.edu*

Female Hooded Warbler (Setophaga citrina) Behavior in Response to a Foreign Object in the Nest

In order to avoid parasitism, maintain nest cleanliness, and defend their broods, many birds have developed behavioral responses to foreign objects in their nests. Female hooded warblers (*Setophaga citrina*) express individual variation in their nesting behaviors. In my experiment, I examined how female hooded warblers react to a foreign object in their nest. A temperature logger (iButton ®) was placed in the bottom of nests during the incubation and nestling period to record nest temperatures during the 2015-2016 breeding seasons. After placing an iButton in the nest, I video recorded each females' behavior at the nest. The initial behavioral response to the iButton was scored on a 1-4 scale, and I used an event recording program to quantify the female's behavior from video recorded 20 minutes following the female's return to the nest. I then calculated the proportion of time spent inspecting the nest and the proportion of time spent exhibiting vigilant behaviors. I predict that females who exhibited more nest inspection behaviors will be higher quality females, and will have higher fledging success. Variation in female response to iButtons may predict the variation in nestling survival, nest temperature, and the amount of vigilant and nest inspection behavior displayed at the nest. Female response to the iButton may also provide insight into how a female responds to a foreign egg in her nest, including a parasitic egg from a Brown-headed Cowbird (*Molothrus ater*). With increasing forest fragmentation leading to increased occurrence of cowbirds in hooded warbler habitat, defensive responses to cowbird eggs and other foreign objects may be selected for.

88.6 WARD, A. B.*; GALLOWAY, K. A.; PORTER, M. E.; MEHTA, R. S.; Adelphi University, Florida Atlantic University, Univ. of California, Santa Cruz; *award@adelphi.edu*

The Morphological Changes Underlying Tail Tapering in an Elongate Group of Fishes

Vertebrates span an incredible range of shapes from almost spherical to spaghetti-like. At one extreme of this possible range are the highly elongate groups, which make up a significant portion of many vertebrate groups. Several studies have noted that body elongation is often coupled with an increase in the number of vertebrae, usually in one specific region. In general, actinopterygians have increased vertebral number in the caudal region whereas increases occur in the precaudal region in sarcopterygians. For fishes, the caudal region of the axial skeleton, is key to understanding potential for locomotor performance as more segments increases the flexibility of the body. In this study, we focused on Ophidiiformes, a group of actinopterygian fishes that include relatively elongate species. We measured 13 morphological and meristic characteristics from 14 species. Through this work we sought to answer 3 questions: 1. What are the relative changes in the length and depth of the caudal vertebrae, 2. How does decreases in the depth of the vertebrae correspond with decreases in body depth, and 3. How does second moment of area (I) change along the caudal region? We found three distinct patterns for variation in the caudal region. We show that species differ in the relative decrease of the vertebrae along the caudal region as well as the degree of tapering of the tail. Finally we found that while I decreases posteriorly along the caudal region for all members of the group, *Dicrolene introniger*, had the lowest I. *Chilara taylori* had the greatest I, indicating a relatively stiffened tail. Given the unique ecology of several of ophidiiform species, this study allows us to further interpret how changes to the caudal region affect locomotor performance and lifestyle in these interesting and highly elongate fishes.

P3.239 WARKENTIN, KM; Boston University; *kwarken@bu.edu*

Development of red-eyed treefrog embryos: a staging table for integrative research on environmentally cued hatching

Red-eyed treefrogs, *Agalychnis callidryas*, are among the best-studied examples of adaptive phenotypic plasticity in hatching timing. Embryos hatch early to escape many egg-stage threats, using cues in multiple sensory modalities. There are well-documented costs of early hatching, for the tadpole stage, and undisturbed embryos typically hatch later. Substantial development occurs between the earliest environmentally cued hatching and the point when most undisturbed embryos have hatched spontaneously (age 3.5-8 days under usual conditions in Gamboa, Panama). However, standard staging tables for anuran embryos (e.g. Gosner 1960) and their prior application to *A. callidryas* (Pyburn 1963) offer little resolution during this period. Stage 23, the last stage with bilateral external gills, stretches from 4 d until after hatching, whenever it occurs. Moreover, the traits differentiating the earliest hatching stages (Stage 22, tail fin circulation; Stage 23, operculum formed) are not the most visible morphological changes during this period. A more detailed system to describe and compare development is needed to facilitate integrative research on developmental changes in behavior, physiology, and performance, as well as environmental effects on development per se. I used periodic observations of egg clutches through development and time-lapse macro-photography to identify a sequential series of marker traits with greater developmental resolution. These include the formation and elongation of external gill branches, melanophore and iridophore development, changes in yolk sac venation, changes in eye structure and angle, beak keratinzation, and division of the yolk sac into gut coils. Using developmental markers to subdivide the plastic hatching period should facilitate the integration of research results across studies.

28.6 WARNE, R*; KIRSCHMAN, L; ZEGLIN, L; Southern Illinois University, Carbondale, Kansas State University; *rwarne@siu.edu*

Microbiome engineering effects developmental plasticity, physiological performance, and disease resistance in larval amphibians

We know little about how microbiome community dynamics equate to microbial function, or how reciprocal interactions between hosts and their microbiome shift to regulate host phenotypic responses to environmental stress and disease. Furthermore, disease susceptibility often varies across ontogeny in animals, and periods of high vulnerability to infection during developmental windows can result in massive die-offs of wildlife. Emerging evidence suggests that gastrointestinal microbiota (GIM) play a central but poorly understood role in host phenotypic plasticity and shifting susceptibility to infections. In particular, GIMs may be central to developmental shifts in vulnerability to intestinal associated pathogens because GIMs undergo remodeling across ontogeny in many vertebrates, and these functional changes can have long-term consequences for adult phenotypes. This project used GIM engineering in larval amphibians, along with ranaviruses as a model developmental and disease system to test how the GIM community influence phenotypic development, physiological performance, and disease susceptibility across ontogeny in closely related species that vary in their resistance to infection. Using a gnotobiotic protocol we found that microbial communities can be manipulated by swapping GIMs between species that differ in developmental patterns and disease susceptibility. Furthermore, we found that altered GIMs influenced rates of amphibian growth, metabolism, development, fluctuating asymmetry patterns, and susceptibility to ranavirus infection. These results provide insight into how GIM composition influence host developmental plasticity, physiological performance, stress tolerance, and disease resistance.

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Consequences of Maternal Nest Site Choice in Invasive Red-eared Slider Turtles in Portland, OR

Red-eared slider turtles (Trachemys scripta elegans) are native to the southeastern United States, but have successfully colonized locations all over the world through human introduction via the international pet trade. Like many reptiles, T. s. elegans is highly sensitive to developmental environments, most notably to temperature due to temperature-dependent sex determination. Thus, the microhabitat that females choose for nesting can have important effects on development, particularly in areas outside of its native range. In this study, we quantified the consequences of maternal nest site choice at a site in Portland, OR, which contains one of the most northern invasive populations. During May and June 2016, we located slider nests and transplanted half the eggs to randomly selected 'nest' sites in order to determine the consequences of maternally-chosen nest microhabitats. At each nest, we measured several microhabitat variables, including distance to water, slope of nest, water content of nest soil, nest temperature, and canopy openness. This project is still underway, but preliminary analyses show that mothers choose nesting locations with significantly less shade cover than expected at random. Nest slope and distance from water did not differ between maternally-chosen and randomly-selected nests. In September, we will return to the study site to collect hatchlings and assess egg mortality, offspring sex ratio, and morphometrics. We predict that maternally-selected nest microhabitats will result in reduced egg mortality and a relatively balanced sex ratio compared to randomly-selected microhabitats. Overall, our results will provide insights into adaptive nesting behaviors in invasive populations, and will provide a better understanding of how competition for nest sites might impact native turtle species that utilize the same nesting habitat as T. s. elegans.

P1.254 WARREN, S.M.*; HOFFMANN, S.L.; KAZEMI, A.; PORTER, M.E.; Florida Atlantic University; *swarre16@fau.edu*

Do You Even Lift? Experimental Investigation of the Effect of Head Morphology on Lift Force Generation in Sharks

Sharks in the hammerhead family (Sphyrnidae) can be recognized by their dorso-ventrally compressed and laterally expanded heads. Head width is highly variable within this family and the head width:body length ratio (HW:BL) decreases over evolutionary time. Additionally, there is a negative correlation between head width and pectoral fin area, suggesting that they may have complementary functions. Previous studies suggest that the pectoral fins, head or both play a role in lift generation, balancing forces on swimming sharks. Our goal is to determine how head morphology affects force generation in two hammerheads and one conventionally shaped shark. We collected CT-scan data from shark heads with varying morphology: blacknose (Carcharhinus acronotus - HW:BL = 15%), scalloped hammerhead (Sphyrna lewini - HW:BL = 26%), and bonnethead (Sphyrna tiburo - HW:BL = 18%). From the CT scans, we 3D printed models that were scaled to one-third of the original shark size. Models were placed in a water tunnel. We measured drag and lift coefficients for Reynolds numbers ranging from 2000 to 8000. Furthermore, we visualized the fluid-structure qualitatively through soap film set up and found a turbulent wake structure surrounded by unsteady laminar flow. To quantify the fluid-structure interaction, we applied Particle Image Velocimetry (PIV) . Quantifying the contribution of the hammerhead cephalofoil to generating lift may provide a better understanding of cephalofoil evolution and inspire biomimetic models.

P3.177 WASS, ED*; MARIAN, AD; GERALD, GW; Nebraska Wesleyan University; *equestrianemma285@gmail.com*

Scaling of Speed, Excess Post-exercise Oxygen Consumption, and Energetic Cost of Lateral Undulation in Cornsnakes (Pantherophis guttatus)

Body size has a large impact on nearly all physiological functions in animals. Because of the effects on underlying physiology, locomotor performance and energetics are also influenced by body size. In most limbed animals, both locomotor performance and locomotor efficiency exhibit negative allometry, meaning that larger animals possess more efficient leg muscles. In limbless animals, data on body size effects on locomotion are more limited. Limbless animals, such as snakes, are capable of utilizing one of many locomotor modes depending on the substrate and the characteristics of the microhabitat being traversed. The most common mode of movement used is lateral undulation, which involves generating force at certain points along the body that make contact with push points, such as rocks or woody vegetation. Our study describes the scaling relationship of speed, excess post-exercise oxygen consumption (EPOC) and energetic cost of lateral undulation in cornsnakes (*Pantherophis guttatus*). Energetic cost of lateral undulation was calculated using the EPOC following 3 min of maximal movement and distance traveled. Although lateral undulation differs biomechanically from limbed locomotion in a number of ways, previous studies have shown a similar cost of transport. We found that speed (cm/sec) scaled with body mass to the 0.32 power, which suggests that speed changes proportionally with body length. Energetic cost scaled to the -0.52 power, which is somewhat lower than has been previously reported for the energetic cost of limbed locomotion (-0.20 to -0.40). Our results suggest that energetic costs of lateral undulation are relatively lower for larger cornsnakes.

9.5 WATERS, J. S.*; TOTH, J.; HARRISON, J. F.; FEWELL, J. H.; Providence College, Arizona State University, Arizona State University; *jwaters2@providence.edu*

Metabolic Allometry and the Scaling of Interaction Patterns with Ant Colony Size

Interaction networks provide the connectivity necessary for the emergence of nonlinear patterns in physical, biological, and social complex systems. One of the most widely observed but least understood of these patterns is the allometric scaling of metabolic rate with organismal body size. Even colonies of eusocial insects exhibit metabolic allometry at the collective level of organization. Many of the hypotheses proposed to explain the mechanistic foundation metabolic allometry rely on resource transport and biophysical constraints associated with the scaling of these networks within individual organisms. In a social insect colony, interaction networks provide the foundation for communication and the emergence of complex collective behaviors including nest architecture, division of labor, and potentially also the social regulation of metabolic rates. To investigate the relationship between interactions, metabolic activity, and colony size, a size-manipulation experiment was conducted in which metabolism was determined by flow-through respirometry simultaneously with observing whole colony interaction networks. A spatially explicit random motion interaction simulation was used to provide a null model against which the results of our empirically determined social insect colony interaction networks could be compared. We found that contrary to the predictions of the model, per-capita interaction rate does not scale with colony size or density and that interactions did not correlate as expected with spatial proximity, suggesting that individuals within colonies actively regulate aspects of their spatial organization and social behavior in a scale-free manner.

113.2 WATSON, CM; Midwestern State University; *charles.watson@mwsu.edu*

Optimal Foraging Frequency and its Physiological "Brackets" in Ectotherms

Feeding frequency in ectotherms can vary based upon both intrinsic and extrinsic factors, including food size and availability, developmental state, body condition, life history, and season. Optimal Foraging Theory, if extended to digestive physiology, would suggest that organisms to feed at a frequency that would maximize conversion of food into body tissue (growth) while minimizing the physiological costs associated with digestion and assimilation. Using juvenile snakes as models, we demonstrate an optimal feeding frequency that maximizes growth when food amount is held constant. Our findings strongly suggest that underlying physiological mechanisms bracketing this frequency is the costs associated with Specific Dynamic Action on the low end and the costs associated with up-regulation of an atrophied digestive system on the high end. We also show that optimal feeding frequency varies among species. The adaptive significance of this phenomenon remains speculative, but it may be influenced by historic prey availability and/or niche partitioning. We continue to gather data on different species to investigate the ubiquity of this physiological trait among ectotherms.

P3.114 WATTS, E. F.*; MILLER, T. T.; MEEKS, E. J.; AMPOSTA, J. P.; FOLTZ, S. L.; MCGLOTHLIN, J. W.; Virginia Tech, Blacksburg; *efw24@vt.edu*

Population Differences in Aggression in Brown Anoles

In brown anoles (*Anolis sagrei*), a lizard native to Cuba and The Bahamas, males defend small territories from other males. Males use a variety of agonistic behaviors, including dewlap flashes, head bobs, and push-ups, to secure and defend territories. In a previous study, we measured these behaviors in wild-caught adults from four Bahamian island populations and found that males from populations in Exuma and North Andros showed were significantly more aggressive than males from populations in Eleuthra and San Salvador. In order to determine whether these population differences were genetic or environmental, we reared offspring from two of these populations (Exuma and Eleuthera) in a common laboratory environment. Offspring were produced from both within- and between-population crosses. When male offspring reached at least 1 year of age, they were sorted into age-matched pairs from the same cross type and placed in a novel enclosure together for 30 min. Males could see each other, but were tethered to prevent physical contact with one another. Each male was tested twice. There was no significant effect of population of origin, suggesting that population differences may be environmental in origin. However, the behavior of opponents within a trial was significantly correlated, suggesting that a male's immediate social environment may be the most important determinant of aggressive behavior. Future work will include more populations and will investigate aggressive behavior in unpaired lizards facing a standardized stimulus.

55.5 WATTS, HE*; ROBART, AR; Loyola Marymount University, Los Angeles, CA; *hwatts1@lmu.edu*

The role of photoperiod in stimulating facultative migration

In obligate migrants, increasing day length and the resulting increase in androgen levels are a key mechanism stimulating the transition to a vernal migratory life history stage. Among facultative migrants, the seasonal expression of a migratory life history stage in the spring has been documented in several species. Yet in these species, the roles of increasing photoperiod and increasing androgen levels in triggering this migratory stage remain unclear. Using the pine siskin (*Spinus pinus*), a nomadic and irruptive migrant, as our model, we investigate (1) whether increasing photoperiod triggers a migratory life history stage in a facultative migrant, and (2) whether an effect of photoperiod might be mediated by increasing testosterone levels as occurs in obligate migrants. Wild-caught pine siskins were held on either winter solstice day length (SD) or a naturally increasing photoperiod (LD) from late-December to June. Behavioral (locomotor activity) and physiological (body mass and fat deposition) indicators of a migratory stage were monitored, and monthly blood samples were collected to measure circulating testosterone levels. LD birds showed increases in locomotor activity, consistent with migratory restlessness, which were not observed in SD birds. LD birds, but not SD birds, also showed increases in circulating testosterone coinciding with the increase in locomotor activity. But, birds in both groups exhibited an increases in body condition consistent with pre-migratory preparations. Thus our results suggest that increasing photoperiod can stimulate the expression of migratory behavior in a facultative migrant, and that this effect may be mediated by an increase in circulating testosterone. However, these mechanisms do not appear to orchestrate initial preparatory changes in body condition such as pre-migratory fattening.

P3.148 WATTS-KERR, C S*; SECOR, S M; University of Alabama; *satchellwk@gmail.com*

Postfeeding energetics of the vinegaroon

The vinegaroon (*Mastigoproctus giganteus*) is a nocturnal desert-dwelling arachnid known for spraying acetic acid from its tail at its attackers. For our study of vinegaroon energetics, we used closed-system respirometry to quantify their postfeeding metabolic profile and specific dynamic action (SDA), the total cost of meal digestion. Following a cricket meal, metabolic rates of vinegaroons at 30°C rose sharply to peak within 12 hours at twice the prefeeding standard metabolic rates (SMR). Metabolic rates then declined, retuning to SMR within 30 hours after feeding. For cricket meals approximately 5% of vinegaroon body mass, SDA averaged 60.2 J, equivalent to 2.85% of meal energy. Across meal sizes (3.5-13% of body mass), SDA increased as a function of meal mass, nearly tripling with a doubling of meal energy. Independent of meal size and energy, the SDA of vinegaroons is similar to that experienced by various species of tarantulas and scorpions, as well as being similar to the SDA of other species of invertebrates.

P3.33 WEBB, AC*; NEUMAN-LEE, LA; WATSON, E; FRENCH, SS; Utah State University; *alisoncarey4@gmail.com*

Time course of the immune response in a non-model organism, Thamnophis elegans

The time it takes for an animal's immune system to respond to and clear an infection is influenced by many factors and can ultimately affect disease resistance and survival. Studies of the time-course of an immune response and the relationship between immune components in non-model organism are limited, but necessary for understanding the immune system in an ecological context. This study uses a non-model reptile, *Thamnophis elegans*, to assess the relationship between innate immune components following a primary injection with sheep red blood cells (SRBC's) and changes in immune response between primary and secondary challenges of SRBC's. To assess the time-course of the immune response, bacterial killing capacity, hemolysis, hemagglutination, and differential leukocyte counts were measured at days 0, 4, 8, 12, and 19 following both primary and secondary injections. Bacterial killing capacity, hemolysis, and hemagglutination increased following the primary injection and bacterial killing capacity and hemagglutination increased following the secondary injection. Of these variables, only hemagglutination increased more following the secondary injection than the primary injection, suggesting some role of acquired immunity in these organisms.

P2.115 WEBBER, MA*; JOHNSON, MA; Trinity University, San Antonio; *mwebber@trinity.edu*

Brain vs. Brawn: Hormonal Mechanisms of Behavior in Caribbean Anoles

Sex steroid hormones play critical roles in regulating the complex suite of social and reproductive behaviors in animals. These hormones control behavior via their activity in the brain regions that influence behavior and in the peripheral tissues that produce it, yet few studies have examined how hormones simultaneously interact with brain, "brawn," and behavior. In this study, we used a group of six species of Caribbean anole lizards to test the hypothesis that species that exhibit higher rates of social behavior will have greater androgen receptor (AR) expression in the brain regions and muscles associated with those behaviors. For each species, we collected behavioral data in the field to quantify the frequency of two behaviors: extension of the dewlap (a throat fan used in aggressive and courtship displays) and copulation. We then quantify AR expression via immunofluorescence in two muscles: the ceratohyoid (the jaw muscle responsible for dewlap extension) and the retractor penis magnus (the tail muscle responsible for retracting the hemipenes after copulation); and in three brain regions that underlie social behavior in anoles (the ventromedial hypothalamus, pre-optic area, and amygdala). Preliminary data indicate that anole species vary in AR expression in the muscles underlying social display, and suggest that this variation is associated with the behavioral frequencies of these displays. This study will be among the first to examine AR expression in multiple tissues associated with behavior, and to do so in an explicitly evolutionary context.

P3.258 WEBER , RC*; HOEKSTRA, LA; JANZEN, FJ; Iowa State University; *rcweber@iastate.edu*

Modeling individual growth of a long-lived reptile Chrysemys picta

Parameters of individual growth comprise and correlate with life history. Painted turtles (*Chrysemys picta*) produce large numbers of untended offspring that exhibit rapid, non-linear growth. Growth slows post-maturation, but may continue indeterminately. Due to their longevity, few robust estimates of individual growth curves exist that span the life of both sexes. Using 26 years of field data, we assessed the ability of three non-linear growth models— the Logistic, Gompertz, and Von Bertalanffy — to predict turtle growth through time. Model comparison supported separate fits for each sex. The Von Bertalanffy growth function proved to be the best fit for both sexes, although female growth was modeled equally well with the Gompertz equation. Bootstrapped confidence intervals of Von Bertalanffy model coefficients show significant differences in sex-specific growth rate. Compared to females, males persistently grow at a higher rate with respect to reproductive maturity, perhaps indicating higher costs of female reproduction.. We discuss these differences in relation to potential variation in sex-specific life-history tradeoffs.

P1.62 WEBSTER, MC; FERRER, RP*; Seattle Pacific Univ.; *ferrer1@spu.edu*

Songbird Foraging Behavior in the Presence of Predator Odors

The importance of olfaction in predator-prey biology has been well established in many habitat types and across diverse taxa. Studies reporting avian responses to predator odors, however, are few and have almost exclusively been confined to laboratory settings. In this study we examined the effects of odors from predator and non-predator urine on songbird foraging behavior in the field. Real-time observations of black-capped chickadees (*Poecile atricapillus*) at feeders in a forest canopy indicated that chickadees fed with significantly fewer interruptions, and spent less time at feeders equipped with cat urine odors than feeders with rabbit urine odors. Chickadee behaviors at ground feeders followed similar trends, but the number of visits was too small for meaningful statistical analysis. Golden crowned sparrows (*Zonotrichia atricapilla*), feeding at ground feeders also exhibited fewer interruptions when exposed to cat urine, but spent equal time foraging regardless of odor treatment. During short-term observation trials, change in food mass was significantly greater at feeders with cat odors than control feeders. An additional experiment was conducted in the field over a two-week period that again tested odors from cat or rabbit urine, but also tested odors from raptor or songbird feces. Food mass change varied widely across all feeders, regardless of odor treatments. These findings indicate that predator odors may alter songbird foraging behavior, but that these behavioral changes may not necessarily result a reduction in food consumption.

P1.266 WEGER, M*; KLEIN, A; WAGNER, H; RWTH Aachen, University of Bonn; *weger@bio2.rwth-aachen.de*

Particle Image Velocimetry measurements on model of barn owl serrations in laminar and unsteady flow

Owls are an order of birds where many species have developed a silent flight. The silent flight is achieved by several wing and feather adaptations, including serrations at the leading edge of the primary feathers which are exposed to the incoming airflow. Serrations are supposed to interact with the airflow and reduce flow separation. Many studies on serrations have been done with artificial serrated leading edges, yet these leading edges do not represent the three-dimensional shape of natural serrations. In this study we constructed a three dimensional model of an array of serrations on a barn owl (*Tyto furcata pratincola*) feather. Enlarged acrylic plastic models were fabricated from this template by 3D-printing and investigated in a water flow channel at Reynolds numbers equivalent to an owl flight velocity of 7.5 m/s. We investigated the model in laminar flow as well as in a vortex street that was created by a half-cylinder placed in front of the model by using Particle Image Velocimetry (PIV) to describe the effects of the serrations on the flow. Our results support previous studies on serrated leading edges that the serrations of owls help stabilizing the incoming flow by creating small-scale turbulences behind the leading edge that dissipate downstream. Unsteady flow is attenuated after impinging the serrations which is demonstrated by a lower RMS-value of the flow velocity parallel and normal to the bulk flow direction downstream of the serrations. We did not find such effects in free stream flow conditions or at a leading edge model with missing serrations that was used for comparison. We conclude that the serrations that can be found in owls help stabilize the incoming air flow in steady and unsteady flow conditions, which can provide flow control, especially during critical flight maneuvers like changing angles of attack and sweep angles of a moving wing.

59.2 WEHRLE, BA*; TADIC, Z; KRAJNOVIC, M; CHERNOFF, K; HERREL, A; GERMAN, DP; WEHRLE, Beck; Univ. of California, Irvine, Univ. of Zagreb, NOAA, C.N.R.S/M.N.H.N; *bwehrle@uci.edu*

Comparative nutrient digestibility between insectivorous and rapid-evolving herbivorous Italian Wall Lizards

A population of Italian Wall Lizards (*Podarcis sicula*) in Croatia has become primarily herbivorous and morphologically distinct from its source population in ~30 generations, making it a compelling example of rapid evolution. However, we know little about what these lizards are capable of digesting from plant material, and whether their physiology is optimized for a plant diet. During lab feeding trials, lizards from the newly herbivorous population digested the organic matter of plant diets more efficiently than did the naturally insectivorous lizards from the source population. However, the two populations did not show differences in digestive efficiency of an insect diet. What mechanism explains the newly herbivorous population's increased digestive performance of plants compared to their source population counterparts? By investigating what nutrients each population is assimilating from their diets, we can better understand the interplay of gut function and digestive performance. We measured both lizard populations' digestive efficiency of protein, carbohydrates, and lipids. If nutrient digestibility is matched to gut function, we should be able to predict what nutrients are assimilated based on digestive enzyme activities in wild lizards. We expect the newly herbivorous population digests carbohydrates more efficiently, as their free living counterparts have higher activities of carbohydrases in some gut regions. We also expect the newly herbivorous population is slightly more efficient at protein digestion, as trypsin activity is higher in their hindguts. Analyses of macronutrient digestion are underway. As this is a study of lizards that have diverged recently, our results may shed light on what functional and performance steps can initially lead to herbivory in lizards.

11.7 WEINBERG, R.B.*; CLANCY, D.; COHEN, C.S.; San Francisco State University; *rachel.b.weinberg@gmail.com*

Genetic Changes Following Fusion in the Invasive Colonial Tunicate Didemnum vexillum

This project examines the fusion outcomes in the invasive colonial tunicate *Didemnum vexillum* to determine how genotypes may be shared between fusion partners in a chimeric colony. *D. vexillum* has extensively colonized hard substrate habitats and poses an ecological threat to native fouling communities in numerous locations including New Zealand, Europe, and both coasts of North America. Like many other colonial tunicate species, histocompatible *D. vexillum* colonies may undergo fusion following physical contact of the tunic. The outcome of allogenic fusion and the level of integration that occurs between zooids and tissues of different genotypes in *D. vexillum* is currently unknown. While the zooids of stolidobranch tunicate species such as *Botryllus schlosseri* are connected through a shared blood vascular system which enables free movement of cells throughout fused colonies, zooids in aplousobranch tunicates such as *D. vexillum* are connected only through the extrazooidal tunic. However, moderate levels of discrimination in the fusion interactions of *D. vexillum* colonies may indicate that there is some integration of cells beyond the fusion line in a chimeric colony. We tracked the movement of microsatellite alleles between fused *D. vexillum* colonies to determine the extent of genetic integration resulting from fusion. Alleles from one colony were found to be present in both colonies two weeks after fusion had occurred, and some fused colonies were found to have lost alleles that were present prior to fusion in one colony. In some instances, allelic movement was unidirectional while in other alleles were found to be exchanged reciprocally between colonies. These results indicate that cells are exchanged following allogenic fusion between *D. vexillum* colonies and that genotypes may be fluid in chimeric colonies.

S11.6 WEIR, P.T.*; DICKINSON, M.H.; Caltech; *peter.weir@gmail.com*

Functional imaging reveals a peripheral map of skylight polarization in Drosophila

The linear polarization of natural sky light is inherently and locally directional, making it useful as a compass cue to a wide variety of insects for directing locomotion. Photoreceptors in the dorsal rim area (DRA) of the compound eye are specialized for detecting the angle of linearly polarized light. In the fruit fly, *Drosophila melanogaster*, central photoreceptors in the DRA are arranged in stacked pairs with identical fields of view and color sensitivities. In larger species of flies the photoreceptors in the DRA form an orderly array of paired polarization detectors, with preferred e-vector angles progressing systematically along the length of the array. We found that this anatomical organization is conserved in *Drosophila*. Using genetically encoded calcium indicators, we directly observed photoreceptor responses to changes in polarization, and found that the pairs of central photoreceptors exhibited orthogonal polarization preferences that varied systematically across the length of the DRA. These functional responses confirm the anatomical findings and provide a map of polarization sensitivity at the input layer of the polarization vision system. In addition, we found that some photoreceptors are inhibited by flashes of light polarized orthogonally to their preferred polarization angle, indicating reciprocal inhibition between photoreceptors in the same column. This inhibition may serve to heighten the polarization contrast of the photoreceptor output. Together, these results indicate that the polarization-vision system relies on a spatial map of preferred polarization angles at the earliest stage of sensory processing. Downstream neurons must decode the spatial structure into angular information for orientation.

123.5 WEISS, TM*; SANE, S; GRAHAM, M; JUNG., S; HEDRICK, TL; SOCHA, JJ; Virginia Tech, National Centre for Biological Sciences, University of North Carolina at Chapel Hill; *talcat@vt.edu*

Jumping on water: field recordings of the skittering frog Euphlyctis cyanophlyctis

Most vertebrates are too heavy to rely on surface tension to traverse the water's surface. Instead, these animals must use inertial-based mechanisms to produce sufficient hydrodynamic forces to stay afloat. Because these mechanisms are both difficult to employ and size-dependent, few vertebrates are able to perform legged locomotion on the water's surface. The Indian skipper frog *Euphlyctis cyanophlyctis* is unique among water surface traversing vertebrates—instead of running, these frogs jump along the water surface. Despite the ubiquity of this species throughout Asia, there have been no quantitative studies on this form of locomotion. To collect the first 3D kinematic data of this water-hopping behavior, we recorded *E. cyanophlyctis* skittering in a pond on the campus of the National Centre for Biological Sciences in Bangalore, India. We found that the frog readily performs this behavior in the wild, enabling the recording of 109 skittering events over the course of a month. Of these recordings, 60 were deemed suitable for 3D analysis, with the frog traveling through the field of view of multiple spatially-calibrated high-speed cameras. Floating frogs at rest were encouraged to skitter using a hydrodynamic disturbance from below, induced with a telescopic plastic pole. Preliminary analysis of the recordings indicates that these frogs are highly maneuverable while skittering—frogs rarely traveled in a straight line while jumping on water, often turning mid-event towards the pond's center. Although frogs often jumped in close proximity to one another (sometimes hurdling other frogs), we recorded no frog-on-frog collisions. In this talk, we discuss the techniques involved in 3D field experimentation and highlight the unique locomotor behaviors revealed from the video recordings.

P1.173 WEISS, TM*; JUNG, S; SOCHA, JJ; Virginia Tech; *talcat@vt.edu*

Variable force production during water-based jumps by the frog Euphlyctis cyanophlyctis

The frog *Euphlyctis cyanophlyctis* is able to leap vertically in the air from a floating position on the water's surface. The mechanism for this impulsive jump is qualitatively similar to that of a frog jumping on land—*E. cyanophlyctis* extends its hindlimbs quickly downwards, with its toes fully spread and foot plane perpendicular to the direction of motion. From water, these frogs are able to control their jump height: when baited with a cricket, a frog will jump within 2 cm of the insect's height. How do frogs modulate launch forces to achieve different jump heights? To address this question, we developed an analytical model of the frog's vertical leap from water to identify kinematic variables that could influence force production. This model predicts that quicker leg extension (shorter propulsion time), greater toe spread (greater foot area), or a longer travel distance of the foot (propulsion length) should increase the amount of force produced, and thus increase jump height. Our preliminary results indicate that, whereas propulsion time does decrease with jump height, it cannot account fully for the required force. Supported partially by NSF 1205642.

P2.182 WELCH, AM; College of Charleston, South Carolina; *welcha@cofc.edu*

Shining a Light on Prozac's Effects on Amphibians: Fluoxetine and its UV Phototransformation Products Reduce Growth and Activity of Toad Tadpoles

Pharmaceutical pollution is an emerging environmental concern, with a wide variety of medications appearing in surface waters around the world. In the environment, UV radiation can cause many pharmaceuticals to transform into related molecules, which may be more toxic than the original compound. Despite increasing attention to the effects of various pharmaceuticals on aquatic life, very little is known about the ecotoxicology of these pharmaceuticals' transformation products. This study examined the effects of the widely-prescribed antidepressant fluoxetine (Prozac) and its transformation products on amphibian larvae. Throughout larval development, tadpoles of the southern toad (*Anaxyrus terrestris*) were exposed either to untransformed fluoxetine or to fluoxetine that had undergone UV phototransformation. Tadpoles experienced similar growth reduction in the two treatments, even though the total concentration of fluoxetine and its transformation products was lower in the phototransformed treatment. This result suggests that tadpole growth was more strongly affected by the transformation products than by fluoxetine itself. By contrast, tadpoles exposed to untransformed fluoxetine showed a more dramatic reduction in activity than did those in the phototransformed treatment, suggesting that the effects on activity were mostly attributable to fluoxetine rather than its transformation products. Because UV phototransformation of fluoxetine results in compounds that may be more harmful than fluoxetine itself, levels of these transformation products, as well as fluoxetine, should be monitored in the environment. More generally, when evaluating the risks posed by pharmaceuticals in the environment, their phototransformation products must also be considered.

44.2 WELKLIN, JF*; LANTZ, SM; BOERSMA, JP; SCHWABL, HG; WEBSTER, MS; Cornell University, Tulane University, Washington State University, Washington State University; *jfw96@cornell.edu*

The Role of Androgens in Mediating Social Environment and Ornament Expression in an Australian Songbird

Hormones are well known for coordinating suites of traits in response to signals in an organism's environment. Perhaps most notably, an increase in androgens is often associated with activation of breeding behavior in response to photoperiod, but an organism's social environment may also be an important signal that has the potential to influence trait expression. In male Red-backed Fairy-wrens, androgens are thought to stimulate molt into nuptial red/black plumage months prior to the breeding season, but the environmental signal that causes this change has been unclear. Males of varying age classes can obtain the sexually-selected red/black plumage, but the timing of this molt within a season is variable and may be influenced by social interactions including potential competitive interactions with other males, or pairing opportunities with females. We combine an experimental manipulation of social environment with a network analysis approach to measure the relationship between social environment and androgens in determining ornament expression in red-backed fairy-wrens.

144.1 WESTERMAN, E.L.*; LETCHINGER, R.; TENGER-TROLANDER, A.; MASSARDO, D.; KRONFORST, M.; University of Arkansas, University of Chicago, University of Chicago , University of Chicago ; *ewesterm@uark.edu*

Presentation or Pattern? The role of movement in butterfly attraction

Female limited polymorphism occurs in multiple species with Batesian mimicry. While frequency dependent selection is often argued as the driving force behind this polymorphism in Batesian mimicry systems, female limited polymorphisms are also found in the absence of Batesian mimicry. In these systems, female limited polymorphism has been shown to be associated with male preference and alternative female mating strategies. It remains unclear whether sexual selection or frequency dependent natural selection drive the maintenance of female limited polymorphisms in systems with Batesian mimicry. Through a series of behavioral assays, we show that female limited polymorphism in the Batesian mimic *Papilio polytes* is not driven by male preference for female wing pattern, as preference for female wing pattern is not the dominant factor influencing male mate selection. Instead, males weigh female behavior more heavily than female wing pattern when choosing whom to court, and court active females, irrespective of female wing pattern. This preference is independent of the genotype of interacting males or females at the locus responsible for the female wing pattern polymorphism, the gene Doublesex. Male emphasis on female behavior instead of appearance may reduce sexual selection pressures on female morphology, thereby facilitating frequency dependent natural selection due to predation risk and toxic model abundance. This emphasis on behavior over morphology during the mate selection process has the potential to facilitate the maintenance of predation driven morphological polymorphisms across animal taxa.

P3.176 WESTON, NG*; POWERS, DR; George Fox Univ., Newberg, OR; *nweston14@georgefox.edu*

Using Deuterium-Enriched Sucrose Solution to Measure the Energetic Importance of Artificial

Feeders are widely used by humans to attract hummingbirds for personal enjoyment. Hummingbirds are key pollinators and the role feeders might play in disrupting pollination cycles is unclear. Current studies suggest that hummingbirds prefer natural flowers over feeders when flowers are available, but the importance of feeders during critical plant flowering periods has not been empirically tested. We studied proportional feeder use in territorial Blue-throated hummingbirds (*Lampornis clemenciae*) and traplining Magnificent Hummingbirds (*Eugenes fulgens*) at the Southwestern Research Station in southeastern Arizona both before and after a major flower bloom. To determine the relative importance of feeders in the hummingbird's diet, feeders were supplied with 25% sucrose solution enriched with deuterium. Urine samples were collected from hummingbirds to compare body water deuterium enrichment to that of the feeder solution. Body water enrichment of both species was above background indicating consistent feeder use. Over the course of the sampling period, body water enrichment of Magnificent hummingbirds averaged 26% while the Blue-Throated hummingbirds was 40% of feeder solution enrichment. This difference was not significant due to individual variability suggesting birds were mobile, and use of alternative food sources in both species. Unexpectedly, when data for all hummingbirds are considered together, birds measured post-bloom had a significantly higher enrichment (18% vs. 59%) than pre-bloom measurements. However, our post-bloom sample size was only 5 birds and likely represents individuals that remained at the study site and frequently used feeders unimpeded by competition.

21.2 WESTRICK, SE*; VAN KESTEREN, F; BOUTIN, S; HUMPHRIES, MM; LANE, J; MCADAM, AG; DANTZER, B; University of Michigan, Ann Arbor, MI, University of Alberta, Edmonton, AB, McGill University, Montreal, QC, University of Saskatchewan, Saskatoon, SK, University of Guelph, Guelph, ON; *westse@umich.edu*

Evolutionary Consequences and Proximate Mechanisms of Maternal Styles in a Wild Mammal

Animal personality, or repeatable individual differences in behavior, may have important ecological and evolutionary consequences. Mother-offspring interactions may be influenced by animal personality, as care provided by females of many mammal species can vary significantly between individuals. These repeatable differences in maternal care are one aspect of personality that has been referred to as "maternal styles" and they may have an impact on the phenotypic development of offspring. Although maternal styles have been studied in many species, the mechanisms behind maternal styles and the ultimate consequences on offspring survival are not well known. In this study, we address potential mechanisms and evolutionary consequences of individual variation in maternal style of a wild mammal. Previous lab studies have shown maternal stress and behavior can influence offspring behavior. With a wild population of North American red squirrels, we observed maternal behavior during and following a simulated predator intrusion to investigate maternal styles. To assess potential mechanisms of variation in maternal styles, we collected data on maternal fecal glucocorticoid metabolite levels, a measurement of stress, during pregnancy and lactation. To assess consequences of maternal styles on phenotypic development and offspring survival, we measured offspring personality using open-field trials, and used recruitment into the population as a measure of survival. This study investigates the influence of stress hormone levels on maternal styles and the impact of maternal styles on offspring recruitment and personality.

120.2 WHEATLEY, R*; LEVY, O; PAVLIC, TP; WILSON, RS; Univ. of Queensland, Australia, Arizona State Univ., USA; *r.wheatley@uq.edu.au*

What Factors Determine Predation Success? Considering Speed, Agility, and Strategy for Predators and Prey

The ability to successfully evade predators is critical to any animal's survival. To predict how well individuals can do this, ecologists primarily measure their maximum sprint speed. But what should a prey animal do when the predator is faster? In this situation, attempting to outrun the predator is pointless - instead, prey animals often exploit the biomechanical trade-off between speed and agility, and try to outmanoeuvre the predator. We constructed an optimality model that predicts the probability of a prey animal with particular speed and agility capabilities evading a predator along escape paths of differing curviness. In order to model a realistic trade-off, we used a function to link maximum sprint speed and agility to a morphological characteristic, limb length; maximum sprint speed increased with limb length, but agility decreased. We ran 400,000 simulations, modelling animals with 40 different limb lengths over 10,000 different escape paths of equal length. We found that animals typically took longer to complete the curvier escape paths, but this effect was negligible in the shortest legged individuals, which were consistently slow. However, animals with shorter legs were significantly faster than longer limbed individuals on curvier escape paths. This suggests that agile prey would be more likely to escape a faster predator if they chose a tortuous escape path. Our simple model provides a basis for more complex models and simulations. We aim to use these models to help answer questions about the escape capabilities of native species against introduced predators, and the influence of habitat.

P1.261 WHITEHEAD, JG*; SOCHA, JJ; Virginia Tech; *whijo23@vt.edu*

A kinematic study of how mallards land on water

Multiple studies have examined how birds land on a perch, but birds can land on a number of different substrates and may employ different kinematic strategies based on substrate. One such substrate is water, which may require different landing behaviors due to the lack of the solidity of a perch or ground. To investigate landing mechanics of birds on water, we are examining the landing behavior of mallards (*Anas platyrhynchos*), which typically land on the ground or water (with occasional apparent hydroplaning), but no longer retain a strong ability to land on a perch. Specifically, we study natural landings of ducks on a local pond in Blacksburg, VA. To record landings for three-dimensional analysis, we use 3 GoPro cameras recording at 4k resolution and 30 fps. The cameras are placed along the shore within a 10 meter radius, synchronized with a sound pulse, and calibrated using a 2.5m wand and easyWand software. To encourage birds to land in the area of interest, we use duck calls and cracked corn as incentives. This method allowed us to measure head position, velocity, and foot extension of mallards as they land on water, and to make comparisons with previous studies of landings on perches. The preliminary results suggest greater variation in the behavior of the mallards, which may be due to changes to in the landing substrate, but differences may also arise from environmental factors such as wind speed and direction. Gaining a greater understanding of how birds land on different substrates will allow us to explore which features of landing behavior may have stronger influences over the accuracy or reliability of the behavior. Supported by NSF MultiSTEPS 0966125 and Virginia Tech GRDP.

129.4 WHITFORD, M. D.*; FREYMILLER, G. A.; CLARK, R. W.; HIGHAM, T. E.; San Diego State Univ. and Univ. of California, Davis, San Diego State Univ. and Univ. of California, Riverside, San Diego State Univ., Univ. of California, Riverside; *mwhitford@ucdavis.edu*

Three-dimensional Kinematics of Rattlesnake Strikes in Nature

Laboratory biomechanical studies on viperid snake strikes have documented exceptional levels of performance. However, it is not known what level of performance snakes attain under natural conditions. Given the vagaries of the natural environment and potential differences in intrinsic motivation, performance under natural conditions could be substantially better or worse than that documented in the laboratory. In addition, the majority of previous strike kinematic studies have relied on lab mice or inanimate objects as surrogates for prey, so we do not know how the level of performance affects success rates in encounters with free ranging prey that have co-evolved with snake predators. Finally, we know little about the relative timing and strike trajectory of rattlesnakes feeding on highly evasive prey. We studied the biomechanics of 32 strike attempts between free-ranging sidewinder rattlesnakes (*Crotalus cerastes*) and desert kangaroo rats (*Dipodomys deserti*). We positioned two high-speed cameras (500 fps) with infrared lighting on rattlesnakes (located using radio telemetry) that were actively hunting and recorded any predatory strike attempts that were made towards desert kangaroo rats. We then quantified the speed, acceleration, timing, and trajectory of movements of rattlesnakes to determine how the level of performance naturally achieved compares to previous lab studies, and to describe how snakes perform when striking natural prey species capable of rapid evasive maneuvers.

118.5 WHITLOW, K.R.*; OUFIERO, C.E.; Towson Univ.; *kwhitlow@uchicago.edu*

A comparative study of locomotor performance in gymnotiform and body-caudal fin swimmers

Fish are highly diverse in their methods of thrust production and are broadly characterized as either body-caudal fin (BCF) or median/paired fin (MPF) swimmers. Gymnotiform locomotion is a subdivision MPF swimming where fish use an elongated anal fin to produce thrust via ribbon-like undulations. Gymnotiform swimmers are hypothesized to be highly maneuverable but limited in their bursting and sustained swimming abilities. However, a study on the escape response of one gymnotiform species (*Xenomystus nigri*) suggests that their acceleratory ability is greater than that of similarly sized BCF swimmers. Little is known about the performance of gymnotiform swimmers, and comparative data with other swimming modes is particularly sparse. To better understand the costs and benefits associated with gymnotiform locomotion, as well as the validity of hypothesized tradeoffs, we investigated the sprint performance and sustained swimming costs of two BCF swimmers (*Devario malabaricus* and *Osteoglossum bicirrhosum*), three pure gymnotiform swimmers (*Apteronotus albifrons*, *Eigenmannia virescens*, and *X. nigri*), and two knifefish which utilize varying degrees of BCF and anal fin undulations (*Chitala ornata* and *Notopterus notopterus*). No differences were detected in maximum sprint speeds across species, suggesting that gymnotiform swimmers are not poor sprinters. Cost of transport analysis showed mixed results across species, but there was no apparent link between locomotor mode and performance. These results demonstrate that variation in swimming mode does not necessarily hinder swimming ability. This study lends support to the proposal that thrust production mechanisms for various types of locomotion (i.e. sprinting, acceleration, and cruising) may be physically decoupled in specialized swimmers, enabling these fish to perform well in all categories.

P1.203 WHITNEY, C/D*; NISHIKAWA, K/C; DALEY, M/A; Northern Arizona Univ., Flagstaff, Royal Veterinary College, University of London; *cw729@nau.edu*

Predicting in vivo muscle force in running guinea fowl using a muscle model based on the winding filament hypothesis.

Accurately modeling muscle forces produced during dynamic animal movements is critical for understanding the biomechanics and neural control of locomotion. Although a large amount of effort has been put towards this endeavor, muscle models are still unable to predict forces during dynamic gaits, especially with perturbations (e.g. moving over obstacles). In this study, we use a novel model inspired by the winding-filament hypothesis to predict forces in running guinea fowl. Lateral gastrocnemius and digital flexor muscle lengths, activations and forces were measured using sonomicrometry, implanted EMG, and tendon buckles, respectively. Two fowls were recorded running on a treadmill under three conditions; level running, running over a 5cm obstacle, and running over a 7cm obstacle. Physiological parameters measured from the birds included the pennation angle, mass of the muscle, and the muscle resting length. The EMG was smoothed, transformed to a percentage of maximum activation, and a time delay was introduced to account for excitation-contraction coupling. The winding filament model (WFM) uses second-order differential equations to describe the kinetics and kinematics of a damped mass-spring system that consists of a contractile element in series with a spring. The contractile element is also in series and parallel with a second spring and damper, which wraps around a pulley and represents the titin protein. Muscle length and activation are inputs to the model, and muscle force is predicted in each time step. The free parameters were optimized and the predicted force was compared to the measured force. Early results show that the WFM-based model can more accurately predict forces during perturbed and level gaits ($R2 = 0.59 -0.86$) than published results using complex Hill-type models.

P2.219 WHITTINGHAM, LA*; DUNN, PO; Univ. of Wisconsin, Milwaukee; *whitting@uwm.edu*

MHC Diversity and Blood Parasite Infection in Migratory and Resident Common Yellowthroats

Pathogens are thought to be important evolutionary forces driving the diversification of immune genes. Genes of the Major Histocompatibility Complex (MHC) are involved in activating the adaptive immune response to pathogens and it is the most polymorphic coding region in the vertebrate genome. MHC diversity has been associated with resistance to a wide variety of pathogens in studies across taxa, including many species of birds. Migratory birds are exposed to a greater diversity of diseases, including blood parasites, than resident birds because migrants visit a variety of different habitats and geographic locations during their annual cycle. As a result, migrant species harbor a greater diversity of parasites compared to non-migrant species. Thus, we might also expect migrants to have greater MHC diversity than residents. Few studies have tested this hypothesis within one species. In this study we examined blood parasite infection and MHC diversity in migratory and resident populations of common yellowthroats (Geothylpis trichas). We found that individuals in the migratory populations had higher prevalence, intensity and diversity of blood parasites and greater allelic diversity at MHC class I than individuals in the resident population. Allelic diversity at MHC class II was similar in all three populations. However, few alleles were shared among populations and as a result there was strong population differentiation at the MHC.

141.4 WIGGINS, WD*; WILDER, SM; Oklahoma State University, Stillwater; *will.wiggins@okstate.edu*

Macronutrient effects on juvenile jumping spider growth

A large body size is important for many reasons, including increases in viable eggs, decrease risk of cannibalism, and increased success in male-male combat. However, building a large body is costly and may require particular amounts and ratios of nutrients. For many animals, especially carnivores on which less is known of their nutritional ecology, the balance of nutrients at which animals maximize growth and body size remains unknown. We manipulated the quantity and nutrient content of flies as prey to test how the lipid and protein content of prey affected the growth of spiders. We measured the body size of 420 F_1 jumping spiders, *Phidippus audax*, raised on 21 different diet treatments ranging from high protein to high lipid across several prey quantities. The ratio of lipid to protein in prey had the largest effect on spider growth in the high prey abundance treatments. Overall, spiders weighed more and had larger body size on diets that were more lipid-biased. Our results suggest that spiders require lipid rich prey for maximal growth. Previous work indicates most prey in nature are lipid poor. Spiders should then either select lipid rich prey over lipid poor prey or find alternative energy sources, like extra floral nectar.

P3.209 WILBUR, JJ*; MORINAGA, G; BERGMANN, PJ; Clark University; *JWilbur@clarku.edu*

Power Analysis of a Novel Nonlinear Phylogenetic Regression Model

It has long been understood that phylogenetic relationships must be accounted for in the analysis of comparative data due to non-independence resulting from common ancestry. However, most available analysis options apply only to linear relationships between variables. To expand upon these approaches, we developed a nonlinear phylogenetic regression model. Building upon a widely used linear phylogenetic least squares regression model (PGLS), we developed a three-parameter nonlinear model that fits a sigmoidal logistic function while accounting for phylogenetic signal in the residuals. Unlike already available logistic regression approaches, ours handles continuous, as opposed to binary, response variables. We conducted a power analysis of this model using simulated data to determine the model's ability to detect sigmoidal patterns at varying species sample sizes (n = 15, 30, 50, 100, 200), variance in the error of the data (SD = 0.5, 1, 2), and slopes at the inflection point of the logistic function (slope = 5, 10, 15, 25). We also quantified the type I error, or the rate at which the model produces false positive results. The nonlinear phylogenetic regression model provides good power in most situations, but drops notably when the number of species falls below 30 with increasing error in the data. This approach can also be extended to any other nonlinear model to allow for greater flexibility in analyzing complex comparative datasets with nonlinear relationships.

104.3 WILCOXEN, TE*; VANA, ER; WROBEL, ER; Millikin University , Miami University-Ohio, University of Georgia ; *twilcoxen@millikin.edu*

Seroprevalence of antibodies against Mycoplasma gallisepticum and Avipoxvirus in nine species of birds with differential access to feeders

Congregation of individuals at high densities is known to increase disease transmission and bird-feeding activities are specifically aimed at attracting many birds to a single location. We surveyed nine potential host bird species for evidence of infection by each *Mycoplasma gallisepticum* (MG) and *Avipoxvirus*, or avian pox. We also examined differences in pathogen exposure at sites with bird feeders and sites without bird feeders. Finally, we compared prevalence of birds with antibodies against MG and avian pox to those that showed physical signs of infection. To test for pathogen exposure, we used indirect ELISA. We found species-specific disease dynamics, as House Finches had a significantly greater likelihood of having antibodies against MG than any other species. Birds at sites with feeders were more likely to have antibodies against MG. Birds at sites with feeders were no more likely to have antibodies against avian pox than birds at sites without feeders and species varied greatly in seroprevalence of antibodies against avian pox. Overall, our findings suggest differential exposure and immune responses to each pathogen among species and that feeders increase the exposure of individuals to MG but not to avian pox, offering valuable new insights into the role of bird feeding activities in disease transmission among birds.

46.6 WILLIAMS, CT*; BARNES, BM; YAN, L; BUCK, CL; Northern Arizona University, Univ. of Alaska Fairbanks, Michigan State University; *cory.williams@nau.edu*

Entraining to the Polar Day: Circadian Rhythms in Arctic Ground Squirrels

In mammals, the master circadian clock, located in the suprachiasmatic nucleus (SCN) of the hypothalamus, is principally entrained to 24h light/dark (LD) cycles, but this cue is seasonally absent in polar environments. Although it has been argued that weak circadian clocks may be a general characteristic of resident polar herbivores, the arctic ground squirrel (AGS) maintains daily rhythms of body temperature (Tb) and behavior throughout its active season which includes six weeks of constant daylight. In this study, we show that while wild-caught AGS remain entrained to a square-wave LD cycle that is in phase with their circadian clocks, their activity and Tb rhythms free-run (tau < 24h) when exposed to successive 6h phase-delayed LD cycles. Following their release from captivity back into the field, AGS with circadian clocks that are 12h out-of-phase with geophysical time rapidly resynchronize (within 48-72 h) their Tb and activity rhythms with their environment under natural conditions of constant daylight. AGS appear to not show "jet lag", the slow realignment of physiological and behavioral rhythms induced by the inertia of a circadian master clock that is intrinsically stable. This may be associated with the low expression of arginine vasopressin (AVP) that we have measured in the SCN of AGS, since AVP is associated with inter-neuronal coupling. Thus, AGS circadian rhythms appear to be highly sensitive to entrainment by relatively subtle parametric changes in the intensity or color of light, yet insensitive to rapid and much more pronounced transitions between light and dark, which they generate naturally due to their semi-fossorial nature.

P3.144 WILLIAMS, J.D.*; EHL, K.M.; RACITI, S.M.; Hofstra University; *biojdw@hofstra.edu*

Impacts of Anthropogenic Debris on Salt Marsh Vegetation: Outcomes and Recommendations for Volunteer Clean-up Efforts

Salt marshes are valuable ecosystems located between coastal salt waters and shorelines, providing many services for wildlife and humans. The vegetation of salt marshes facilitates these services, therefore damage or disturbance to these plants can have negative impacts at local to global scales. This study investigated the recovery of vegetation on a Long Island, NY salt marsh over two growing seasons, after the removal of large wooden debris (mostly docks) that was deposited during storms. The impacts of the debris on salt marsh plants were tested by measuring the percent cover and shoot density of the vegetation monthly after debris removal. The consequences of removing wooden debris during the fall versus spring were also explored. Two years after the removal of the debris, regardless of when debris was removed, the salt marsh vegetation cover was not significantly different from controls. In addition, the effects of trampling by volunteers during debris removal were monitored and after one growing season, trails used during a single clean-up effort had a mean vegetation cover of 67% whereas those that were used during multiple clean-up efforts had only 30% cover. This study expands our understanding of the impacts of large anthropogenic debris on salt marsh vegetation and the potential for vegetation recovery after debris removal. Based on these findings we will present recommended strategies for organizing effective salt marsh clean-up efforts.

P1.264 WILLIAMS, M*; JACKSON, BE; Longwood University; *jacksonbe3@longwood.edu*

Field 3D Kinematics of Unsteady Flight in Wild Blue Jays

Flight imposes numerous mechanical and evolutionary constraints on those animals that possess the ability; hence bird flight has been a focus of biomechanical studies for decades. Most of our understanding derives from laboratory studies, often of birds in wind-tunnels performing steady flight, or in other artificial scenarios. However, flight evolved and is routinely performed in wild and variable settings where successful take-offs and landings are critical. New open-source software, *Argus*, and the availability of ruggedized consumer grade cameras permit 3D reconstructions of movement of wild animals in natural settings. We used three GoPro Hero4 Black cameras to film (240 fps) wild Blue Jays (*Cyanocitta cristata*) approaching and departing a bird feeder in Farmville, VA, U.S.A. After calibrating the three-dimensional volume with a wand of known length, correcting for lens distortion, and synchronizing the videos using the audio tracks, we were able to reconstruct the 3D positions of ten points on the birds' bodies and wings within the filming volume (~ 1 x 1 x 3 m). We calculated several kinematic factors, which varied among flights, but from which basic mechanical hypotheses can be examined. For example, one bird approached in a side-slip glide and relied on the last three wing beats to slow its velocity and reposition its body before landing. In this event, the second to last wing beat demonstrated an upward wing stroke plane angle of 7 degrees from horizontal, suggesting a reversed net thrust vector, and coinciding with the greatest deceleration in the approach. The naturally occurring behavioral variation among flight events provides not just a view into mechanics of flight in field conditions, but also the opportunity to examine the full variation of mechanical solutions to flight in the wild.

S4.12 WILLIAMS, Caroline M*; RAGLAND, Gregory J; U California, Berkeley, U Colorado, Denver; *cmw@berkeley.edu*

Evolutionary impacts of seasonality: synthesis and directions forward

Organisms living in seasonal environments experience fluctuating selection pressures that influence their ecology and physiology, and drive their evolution. Classic work by Dobzhansky and early researchers identified seasonal fluctuations as a potentially important mechanism maintaining genetic polymorphism in natural populations, and studies of seasonal polyphenism and phenology have advanced our understanding of life history evolution. Evolutionary and ecological responses to seasonality can be very rapid, and predicting such responses to contemporary climate change is a pressing concern. Recent advances in the field are moving towards greater understanding of the impacts of seasonality on genomic and physiological evolution, promising to illuminate the importance of seasonality in generating adaptation and constraining evolution. These advances promise more realistic, empirically informed models of biological responses to changing seasonality. Yet, achieving this goal requires interdisciplinary approaches that can identify some rules that predict what types of genetic and ecological changes we might expect from a change in a given environmental driver. The symposium Evolutionary Impacts of Seasonality brings together a diverse array of research approaches and study systems to work towards such integrative models. We will synthesize the approaches and conclusions of these and other recent studies in this area, highlighting transformative questions emerging from research across organisms, and suggesting how this research can best be integrated, conceptually and quantitatively.

S3.8 WILLIS, C.K.R.*; CZENZE, Z.C.; DAVY, C.M.; FLETCHER, Q.E.; MAYBERRY, H.W.; MCGUIRE, L.P.; MUISE, K.; NORQUAY, K.J.O.; WEBBER, Q.M.R.; Univ. of Winnipeg; *c.willis@uwinnipeg.ca*

Tradeoffs governing the physiological ecology of hibernation in endangered bats

Energetics of mammalian hibernation can be considered in terms of three phases: positive energy balance before winter; negative energy balance during winter; and spring recovery when positive energy balance is restored. Hibernation itself is comprised of long torpor bouts (periods of low body temperature (Tb) and metabolic rate) interrupted by brief arousals to normal Tb. The function of arousals is not fully understood but they are obligatory for mammals and account for most winter energy expenditure. Most data on hibernation come from rodents but insect-eating bats have potential for studying tradeoffs affecting all three phases of hibernation. Our group has been studying little brown bats (Myotis lucifugus) to test the hypothesis that similar tradeoffs influence all three phases of hibernation for rodents and bats despite dramatic differences in hibernation ecology and behavior. Data collected using temperature telemetry, infrared video, passive transponders (PIT tags) and plasma metabolite analyses suggest that individual and group characteristics (sex differences in reproductive timing, individual personality), and environmental factors (weather, winter duration) influence hibernation energetics and phenology. Our measurements of cortisol in claws of bats that survive the devastating fungal disease white-nose syndrome (WNS) highlight the trade-off between winter energy expenditure and summer reproduction, and suggest that effects of winter stressors carry over from one season to the next. This work has implications for understanding the evolution of hibernation, ecology of temperate-zone bats, and potential value of management strategies proposed for WNS.

80.4 WILSON, K.M.*; FORSGREN, K.L.; BURLEY, N.T.; University of California, Irvine, California State University, Fullerton ; *kkmurphy@uci.edu*

Feather Bacteria and Reproductive Success in the Zebra Finch

Avian plumage maintenance is expected to be costly in terms of allocation to uropygial gland antibacterial secretions as well as the time spent preening. However, the extent to which or whether feather maintenance costs compete with reproductive demands to impact offspring survival and quality is largely unknown. Resources permitting, zebra finches can breed in the same season in which they hatch. Thus, the rate at which birds develop secondary sexual traits should be a meaningful index of offspring quality. In order to manipulate feather bacteria loads, breeders were cage-housed and treated 3 times weekly with 0.5% chlorhexidine suspended in saline, saline only or handling only. Bacterial samples were collected prior to treatment assignment, and at 3 stages in the nesting cycle: during incubation, after hatching, and after fledging. We predicted that treatment with chlorhexidine would result in lower colony forming units across the reproductive cycle, higher hatchling survival, and more rapid offspring development. All of these predictions were met. Collectively, our results indicate that feather bacteria impaired reproductive performance. To assay possible costs of combatting feather bacteria, we also considered treatment and breeding stage effects on adult uropygial gland volume, and time spent preening.

P3.81 WILSON, E*; HELM, BR; ROYAUTE, R; MALLINGER, RE; RINEHART, JP; GREENLEE, KJ; BOWSHER, JH; DePauw University, North Dakota State University, Fargo ND, USDA-ARS Sunflower and Plant Biology Research, Fargo ND, USDA-ARS Insect Genetics and Biochemistry, Fargo ND; *bryan.r.helm@ndsu.edu*

Nest Building 101: Nest architecture reflects behavior and ecology of Megachile rotundata

Behavioral Syndromes occur when behaviors are correlated together. Studying behavioral syndromes allows a more integrated view of behavior by recognizing that behaviors often don't operate independently from one another and considers sources of behavioral variation both within and among individuals. The alfalfa leaf cutter bee, *Megachile rotundata*, constructs nests that require gathering leaf materials to form a linear series of cells, foraging for provisions, and making reproductive choices including offspring number, provisioning, and sex. Thus, nest construction may be an example of a behavioral syndrome that could be examined by measuring the architecture and composition of each nest. Our aim was to observe within and among-individual variation in multiple, distinct nest-constructing behaviors by examining features of *M. rotundata* nest architecture. We successfully identify three behavioral modules that constitute a nesting behavioral syndrome: nest protection, leaf foraging, and pollen/nectar provisioning. As an example, we found that the number of leaves invested into each nest cell is uncorrelated to the cell provisioning. This suggests that cell leaf foraging and provision foraging are independent behavioral components. Second, our results indicate that individual differences in nest-constructing behaviors account for 30% of the total phenotypic variation observed in the population and that individual females are tasked with tradeoff choices when expressing different behaviors. Thus, examining the architecture of nests can serve as an enlightening proxy for characterizing behaviors directing nest construction.

P1.144 WILSON, RC*; LUTTERSCHMIDT, DI; Portland State University; *rwilson@pdx.edu*

Identification of a leptin-like protein in red-sided garter snakes and its effects on reproductive behavior

The cost-benefit paradigm between reproduction and survival is a common biological theme. Despite much research, the endocrine mechanisms that allow organisms to mediate trade-offs between reproducing and surviving are poorly understood. Leptin has been implicated in mediating these trade-offs. In mammals, leptin is synthesized by adipocytes in proportion to cell size, and thus reliably indicates energy status. However, studies in non-mammalian vertebrates suggest the role of leptin is not well conserved. To better understand if and how leptin mediates reproductive trade-offs across taxa, we identified a leptin-like protein in red-sided garter snakes (*Thamnophis sirtalis parietalis*). We utilized a combination of enzyme immunoassay and Western blot to determine the presence of leptin in plasma, liver, and adipose (i.e., fat body) tissues. We identified a leptin-like protein in the plasma of both male and female snakes. Western blot results indicate a higher concentration of leptin in plasma than in fat bodies or liver, consistent with the hypothesis of constitutively-released leptin. Next, we asked if exogenous leptin treatment influences reproductive behavior of snakes. Leptin did not significantly alter male courtship intensity. In contrast, the proportion of leptin-injected females that copulated was higher than that of control-treated individuals. There were no differences in latency to copulate or the duration of copulation between groups. In addition, we observed no differences in the morphometrics of males that succeeded in copulating with leptin- vs. control-treated females. These results indicate that leptin is involved in reproductive "decision making" in female garter snakes, and also suggest that the role of leptin in mediating reproductive trade-offs may be conserved.

12.7 WILSON, A*; HUBEL, T; DEWHIRST, O; ROSKILLY, K; WEST, T; LORENC, M; DIACK, R; BARTLAM-BROOKS, H; BENNITT, E; GOBOLEK, K; MCNUTT, J; CURTIN, N; RVC, University of Botswana, Botswana Predator Conservation Trust; *awilson@rvc.ac.uk*

Biomechanics of predator prey interaction in four African mammals- Is it an arms race?

Carnivores hunt herbivores and herbivores evade carnivores. One facet of this, exemplified in the medium sized mammals of the African savannahs is pursuit predation. Authors have proposed that there is a strong selection pressure for both predator and prey to evolve to be ever faster and more maneuverable since hunt outcome and success rate are critical to survival. Here we focus on comparing athleticism during hunting in a large and a small wild pursuit predator, the lion (*Panthera leo*) and cheetah (*Acinonyx jubatus*) and their most common prey animal (zebra (*Equus quagga*) and impala (*Aepyceros melampus*). We chose three metrics, the first is muscle fibre maximum contraction velocity and muscle power which is a determinant of acceleration and absolute speed. The second metric is whole body acceleration (and deceleration) performance which whilst dependent on muscle power and mass is a measure of actual performance via factors including body shape, anatomy and grip. The third metric is turning performance (lateral acceleration and heading rate as a function of forward speed) which could be limited by grip, leg strength and anatomical specialisation. The studies were undertaken on free ranging wild animals in Botswana. Muscle measurements are made on skinned muscle fibres collected via biopsy during collaring events and locomotion (including hunting events) via collars of our own design that combine high rate inertial measurement (accelerometer, gyroscope and magnetometer) and high rate GPS measurements (Wilson et al 2013). The data show pairwise differences in performance that cannot be fully attributed to the inter species differences in muscle physiology. These data will be discussed in the light of the different ecological pressures the animals are subject to.

12.5 WILSON, RS*; LEVY, O; WHEATLEY, R; PAVLIC, T; The University of Queensland, Arizona State University; *r.wilson@uq.edu.au*

Predicting escape success of terrestrial animals along paths of varying curvature

Most of the time, terrestrial escape speed is measured as the fastest an animal can run in a straight line, and it's assumed that this is a relevant index of survival. But animals rarely run this way in nature—instead, they often change direction, making their paths more curved than straight. To address this mismatch, we designed a mathematical model that uses acceleration, deceleration, maximum sprint speed and turning ability to predict an individual's escape performance in paths of varying curvature. Our model suggests that smaller individuals (prey) are more likely to escape larger individuals (predators) by running along a curvy path: larger individuals are faster on a straight line. Using only these four parameters, it may be possible to estimate the escape success of prey (vs. predators) in nature and evaluate the extinction risk of natural populations following the introduction of feral predators.

P2.230 WILSON, RS*; CLEMENTE, C; KASUMOVIC, M; The University of Queensland, University of the Sunshine Coast, University of New South Wales; *r.wilson@uq.edu.au*

Teaching evolutionary principles using games: escape speeds, performance and life history trade-offs

In collaboration with the software designer *arludo*, we developed a novel game-based, approach to teaching key concepts in evolution - including natural selection, performance and energetic trade-offs, and foraging strategies. In this app, students become the predators in a game that simulates encounters between predators and prey. Students observe how the actions of the predators (themselves) affect the frequency of escape speeds of prey and the rate of this change across generations. In essence, students can observe how their prowess as predators affects the evolution of escape speeds in a simulated population of prey. To do this, students are asked to ‘capture' simulated on-screen prey (dots on screen) that move across the computer's screen (varying population size) by touching them on the tablet's screen. The better one is at hitting the prey on screen (eating them) the fewer individuals that will remain in the population. Only those individuals that escape being captured get the opportunity to breed and produce offspring for the next generation. We are then able to vary (i) population size, (ii) mean and variance of speed for the prey (in the first generation), (iii) agility of prey, and the (iv) trade-off between speed and agility, and then observe the consequences of these factors. Because success in the game is based on the accumulation of energy, by varying the energetic benefits of capturing prey and the costs of attempting to capture prey, one can also assess how the best predator strategy changes with energetic constraints. This app is useful for both demonstrating the simplicity of natural selection to non-scientists and for higher-level science students than are able to design their own experiments by varying traits and energetic constraints in the game and then observing the outcomes.

P1.145 WILSTERMAN, K*; GOTLIEB, N; KRIEGSFELD, LJ; BENTLEY, GE; UC Berkeley; *kwilsterman@berkeley.edu*

Mapping the ovarian pathways involved in stress-induced reproductive dysfunction in mice

In mammals, progesterone production by the corpus luteum (CL) in the ovary is necessary for maintenance of early pregnancy. Chronic stress inhibits progesterone production, and thus results in pregnancy loss in rodents. This effect can be rescued by progesterone supplementation. While substantial research has focused on the downstream mechanisms by which low progesterone contributes to pregnancy loss, the stress-induced changes in receptor signaling and steroidogenic gene expression in the ovary that drive low progesterone production are not well understood. We used a rodent model to investigate proximate mechanisms in the ovary that cause low progesterone production during early pregnancy in response to chronic stress. Female mice were mated and randomly placed in stress or control groups. Stressed animals were restrained for four hours per day for four days following mating. Tissue and plasma samples were collected 5.5 days after mating. On day 5.5 of pregnancy, stressed animals had significantly lower plasma progesterone than control females ($P < 0.01$). Expression of the long-form prolactin receptor in the ovaries was lower in stressed females ($P < 0.05$) and was significantly correlated with the expression of steroidogenic enzymes StAR (steroidogenic acute regulatory protein) and P450scc (cholesterol side-chain cleavage enzyme). There was no difference in expression of the S2 or S3 prolactin receptor genes or luteinizing hormone receptor between groups ($P > 0.10$). Our data indicate that stress disrupts several components of the ovarian steroidogenic pathway, possibly via altered expression of the long-form prolactin receptor in the ovary. Ongoing work will test whether these changes in ovarian gene expression during pregnancy persist throughout gestation and impact overall fecundity.

P3.259 WINN, L*; FLAMMANG, BE; New Jersey Institute of Technology; *winn@njit.edu*

Fluid dynamics of chondrichthyan egg cases

Chondrichthyan development within an egg case may take multiple years before hatching. During the development of the embryo, flow is required through the egg case to move oxygenated water and metabolic wastes in and out of the egg case. In the egg cases of some skates and chimaeroids the embryo actively pumps water through the case by undulating its tail; however, some catsharks (*Apristurus* and *Parmaturus*) do not actively ventilate their egg cases and the water within the case is passively pumped through by hydrodynamic forces. The relationship between permeability, functional morphology, and fluid dynamics of egg cases are yet to be fully understood and are poorly represented in the literature. Here we show basic flow models pertaining to the effects of morphology and environmental factors on fluid dynamics surrounding egg cases. Using 3D printed models of egg cases and volumetric flow analyses, we established a previously unknown metric of flow probabilities based on morphological properties. Findings from this work contribute to the understanding of the effective relationship between an organism and its environment.

P3.50 WINTERS, GC*; KOHN, AB; HATFIELD, L; PAULAY, K; LAUX, R; POLESE, G; DICOSMO, A; MOROZ, LL; Whitney Lab Univ Florida , Bridgewater College , Humboldt State, U. Naples Federico II; *gabrielle.winters@gmail.com*

Molecular organization of Octopus brains: Insight into unique memory center signaling

Cephalopods (*Octopus*, Squid, Cuttlefish, *Nautilus*) exhibit behavioral flexibility that rivals that of many mammals. The Vertical Lobe (VL), a cephalopod-specific memory circuit, parallels mammalian analogues (hippocampus) in cell number and function, but evolved independently in molluscs. We integrated Next-gen sequencing technology and bioinformatic analyses, followed by anatomical validation, to identify molecular maps of signaling molecules implemented in cephalopod memory circuits. We produced transcriptomes of various Octopus neural tissues (VL, CNS, SFL, Arms), and individual cells from sub-populations within the VL circuit: Amacrine (Am) Interneurons and Large Efferent (LE) Neurons. We mapped these transcriptomes to a publically available Octopus genome and our gastropod transcriptomes including *Aplysia*. We identified 16,194 transcripts in the VL and found ~25.5% appear to be cephalopod-specific. Next we used targeted and unbiased computational predictions and manual annotation to identify putative signaling molecules form the VL transcriptomes. We have cloned and localized 11 neuropeptides (NP) to components of the VL circuit. NPX3 is abundantly expressed in the cell bodies of the SFL, where the VL circuit originates and NPX1 & 2 localize to the AM cell bodies of each VL gyrus. Among the 7 NPs that localize to the VL LE neurons, 2 unique cephalopod NPs, NPX4 & 5, are abundant in *Octopus*, but absent in the ancestrally branching *Nautilus* (which lacks a VL). This expansion of signaling molecules in the VL circuit may be a key feature of unique memory systems of cephalopods, implying extensive parallel evolution of cephalopod brains and memory circuits.

P3.175 WINWARD, J*; IONESCU, A; JIMENEZ, A.G.; Colgate University; *ajimenez@colgate.edu*

Oxidative stress: the balance between pro/anti-oxidants, and its implications for lifespan in the domestic dog, Canis lupus familiaris

Small mammals typically have lower whole animal metabolic rates compared with large mammals. As a result, large mammals with higher whole animal metabolic rates have longer lifespans than small mammals. However, across domestic dog breeds (*Canis lupus familiaris*), we find that although small breed dogs tend to have lower whole animal metabolic rates than large breed dogs, they also tend to live longer, an opposite pattern to most mammals. We were interested in the cellular mechanism that may allow for small breed dogs to age slower compared with large breed dogs in the context of oxidative stress. Primary dermal fibroblasts were grown in tissue culture from domestic canine skin samples that were obtained from veterinarians. Dogs were grouped by age and breed size. We measured rates of RS (reactive species) production, reduced glutathione, mitochondrial content, basal and maximal rates of lipid peroxidation in primary fibroblasts from dogs. Our results show that large breed dogs have higher concentrations of reduced glutathione throughout their lives compared with small breed dogs. In general, mitochondrial content decreases as breeds of all sizes age, though, RS production show increases in older large breed dogs. We also see significant differences in maximal lipid peroxidation in large breed puppies, suggesting that cellular damage starts accruing at a young age. Thus, large breed dogs, with their higher whole animal metabolism and faster growth trajectories, also show an increased production of pro-oxidants and higher lipid peroxidation damage, thus, demarcating a potential mechanism for their decreased lifespan compared with small breed dogs.

79.7 WOFFORD, SJ*; MOORE, PA; Bowling Green State University; *sjwofford1@gmail.com*

Sense and Chemosensory Ability: How does blocking olfaction alter contest assessment in crayfish?

Animals must gather information from their environment to make decisions that maximize fitness and minimize injury and energy use. These decisions (i.e. assessment strategies) are especially important in the context of fighting behavior. The assessment strategy used by a particular species is dependent upon neural complexity as well as surrounding environmental factors (context). One such context is the ability of opponents to communicate effectively through various cues or signals. Degradation or absence of a signal can significantly alter contest dynamics, increasing fight times due to the inability to accurately assess oneself or an opponent. This study examined whether alterations in chemical communication affected the assessment strategy used by crayfish (*Orconectes rusticus*) by staging one-on-one contests. Mixed sex contests were randomly assembled and one individual was chosen to undergo lesioning, which impaired chemosensory abilities. Dyads were composed of either size matched opponents or opponents that differed in size (up to 30% difference in body length). Saltwater lesioning was used to lyse chemical receptors on the primary chemosensory organ while leaving mechanoreceptors intact. In order to elucidate mechanistic differences in the decision making paradigm (i.e. assessment strategy) for males and females, we compared the use of a quantifiable signal using chemical visualization techniques. Both individuals were injected with a fluorescent dye, and fights were observed under black lights. Trials were videotaped and analyzed for the type of assessment strategy in use as well as any differences in the timing or duration of signal release. Results indicate that blocking chemical communication appears to alter decision making in mixed sex crayfish contests.

P2.77 WOJCIECHOWSKI, MS*; PRZYBYLSKA, AS; NOWAKOWSKA, A; JEFIMOW, M; Nicolaus Copernicus Univ., Poland; *mwojc@umk.pl*
Seasonally heterothermic rodent increases antioxidant defense in winter, while oxidative stress remains constant
As days shorten and ambient temperature decreases towards winter some temperate-zone mammals develop heterothermy. However, not all individuals respond equally to these changes; photo-responders use daily torpor, while non-responders are normothermic throughout a year. Since responders are potentially subjected to higher oxidative stress resulting from rapid increase in metabolic rate during frequent arousals from torpor, we hypothesized that their antioxidant capacity would be higher than in non-responders. To test the prediction that responders and non-responders differ in oxidative capacity and antioxidant potential, we measured concentration of reactive oxygen metabolites (ROM, mg H_2O_2 dl^{-1}) and biological antioxidant potential (BAP, µmol vitamin C l^{-1}) using the FRAS4 evolvo system (H&D, Parma, Italy). We used 80 male and 80 female Siberian hamsters (*Phodopus sungorus*) which were acclimated to summer (16L:8D, 20°C) and then to winter (8L:16D, 10°C). After each acclimation, ROM and BAP were measured in blood drawn from the retro-orbital sinus. We found that responders and non-responders did not differ in the ROM or BAP. However, antioxidant potential increased from summer to winter by ~20% ($p<0.001$), and it was true for both sexes and phenotypes. Irrespective of season and phenotype, females had lower ROM than males ($p<0.05$). These results do not support our original hypothesis. It looks however, that Siberian hamsters increase their antioxidant defense in winter. Responders did not differ from non-responders, as both rely on non-shivering thermogenesis to cope with cold when active on the daily basis. The study was supported by the grant #NCN 2014/13/B/NZ8/04698.

63.5 WOLF, Z*; JUSUFI, A; VOGT, D; WOOD, R; LAUDER, G; Harvard University; *zwolf.mlxvi@gmail.com*
Integration of soft robotic actuators to investigate body-caudal-fin swimming in fishes
The recent development of soft robotic actuators (pneunets) allows for the investigation of actively controlled models of fish locomotion, in contrast to the historic approach of using passively flexible foils. Pneunets can be manufactured using an array of silicone rubbers with or without directional exterior reinforcements, and by using flexible 3D printing technology. Previous work has begun to explore the use of silicone pneunets for aquatic locomotion by bilaterally attaching two pneunets to a flexible plastic foil. Activation of pneunets resulted in positive thrust and undulatory propulsion. In addition to expanding the parameter space in frequency and pressure amplitude, this project compares the performance of pneunets fabricated using different materials and techniques and moves toward achieving more fish-like, full body undulatory movement using four pneunets arranged in a quad configuration. The assembled apparatus was suspended in a recirculating flow tank attached to an ATI 6-axis force-torque sensor. We measured thrust, lateral force, and amplitude of oscillation. We tested our ability to maintain amplitude in the face of fluctuating frequency. Ultimately this project will move towards implementing a closed loop system using strain sensors and other feedback mechanisms to better understand the dynamics of aquatic propulsion.

77.2 WOLF, C; WOLF, S; VOISIN, D; KOVACS, J*; John Hopkins University, Georgia State University, Spelman College; *jkovacs@spelman.edu*
Evidence of indirect symbiont conferred protection against predation in pea aphids
Non-essential, facultative, symbiotic microbes can provide their hosts with protection from parasites, pathogens, and predators. Recent work has found that two facultative secondary symbionts *Serratia symbiotica* and *Hamiltonella defensa*, provide their host, the phloem-feeding insect the pea aphid (*Acyrthesiphon pisum*), with protection against predation from the lady beetle *Hippodamia convergens*. By reducing the fitness of the aphid predator, aphid secondary symbionts indirectly defend their host against predation, since aphids reproduce clonally and are often found in large genetically identical groups. We have recently extended this work to look at the fitness effects of aphid secondary symbionts (*Serratia symbiotica*, *Hamiltonella defensa*, and *Regiella insecticola*) in another aphid predator, the invasive lady beetle *Harmonia axyridis*. Similar to previous results, we found the survival of juvenile lady beetles to be significantly reduced for those that were fed aphids with secondary symbionts *Serratia*, as well as *Regiella*, however no fitness costs were found for those fed aphids with *Hamiltonella* or no symbionts. The presence of aphid symbionts in the larval diet of *Ha. axyridis* was also found to significantly affect development time to adulthood. Interestingly, the survival effects appear to be different between the species of predator. Additionally, for both predator species, different symbionts had different affects suggesting that each symbiont reduces the survival of the predator through a different mechanism. This work provides yet another example of the often far-reaching and unexpected effects that endosymbionts can have in ecological systems and highlights the importance of expanding our study of endosymbionts to include the many ecological interactions of their host species.

S7.3 WOLFE, JM; Massachusetts Institute of Technology; *jowolfe@mit.edu*
Arthropod ontogeny and phylogeny: Perspectives from fossils and phylogenomics
The exceptional preservation of fossils attributable to larval stages opens a window for studies of arthropod developmental biology in the ancient oceans. The phylogenetic placement of larval fossils provides unique but essential challenges, as this material represents some of the very oldest arthropod fossils (early Cambrian, 514 Ma) and thus occupies a key position in major crown group splits. New transcriptomic data and new fossil calibrated phylogenies, and their implications for the evolution of larval biology and ecology will discussed.

71.2 WOLFF, GH*; LAHONDÈRE, C; VINAUGER, C; ARNOLD, BY; ALZATE, DG; RIFFELL, JA; Univ. of Washington; *gabwolff@uw.edu*

Neural Basis of Host Preference Across Mosquito Species

Over 3,500 mosquito species have been described in the family Culicidae, inhabiting every continent except Antarctica. Preferred hosts vary widely across mosquito species from humans and other mammals to reptiles, birds and arthropods. Some species may be specialists or opportunists and some species do not blood-feed at all, including all members of the genus *Toxorhynchites*. Anthropophilic disease-vector mosquitoes have a significant impact on global ecosystems, epidemiology, and economies by their impact on human health and welfare, yet little is known about why they preferentially feed on humans and certain subpopulations in particular. One factor may be that mosquitoes can learn and remember sensory information such as chemical odors associated with the best (and worst) hosts. This learning and memory has been shown to be heavily modulated by biogenic amines such as dopamine and serotonin. In order to understand why mosquitoes seek to bite their preferred hosts, we compared receptivity to a panel of odors, ability to form associative olfactory memories of these odors, and expression patterns of dopamine and serotonin in olfactory brain centers across the species *Aedes aegypti* (anthropophilic), *Toxorhynchites amboinensis* (nectarivorous), and *Anopheles stephensi* (anthropophilic). Results indicate a heterogeneity of biogenic amine expression in the antennal lobes which may have a relationship with encoding of olfactory memories that are likely involved in host preference behaviors.

74.3 WOLL, S C*; PODRABSKY, J E; Portland State University; *scwoll@pdx.edu*

The role of Insulin-like growth factor signaling in the regulation of entrance into diapause in embryos of the annual killifish, Austrofundulus limnaeus

Development in the annual killifish *Austrofundulus limnaeus* can follow two distinct developmental trajectories. Typical development includes the entrance of embryos into a state of metabolic and developmental arrest termed diapause. Alternately, embryos can escape diapause and develop directly without pause. These two trajectories are characterized by differences in the rate and timing of developmental, morphological, and physiological traits. Insulin and Insulin-like growth factor (IGF) signaling (IIS) is known to regulate entrance into diapause in a variety of invertebrates. Here I report stage-specific expression of IGF-I and II proteins and their associated mRNA transcripts. Patterns of IGF-I protein expression are consistent with IGF signaling playing a major role in supporting the escape trajectory. In addition, treatment of embryos with a potent inhibitor of the IGF-I receptor (IGF1R) mimics the diapause developmental pattern even under conditions that should favor direct development. Evaluation of mRNA gene expression patterns in the two developmental trajectories suggests a role for IGF-I signaling through the RAS-MAPK-ERK pathway, which may be promoting the escape phenotype. Additionally, IGF-I activity may be enhanced in escape trajectory embryos though upregulation of IGF binding protein 2 (IGFBP-2). These data suggest a major role for IGF signaling in the promotion of the escape trajectory, and thus we predict that specific mechanisms are in place in diapause-bound embryos that block IGF signaling and thus promote entrance into diapause. The data presented here suggest that blocking IGF signaling is critical for induction of diapause, but also suggests that other signaling pathways are likely also at play.

25.3 WOMACK, MC*; STYNOSKI, J; LEMMON, AR; LEMMON, EM; METZ, M; HOKE, KL; Colorado State University, Fort Collins, Florida State University, Tallahassee, Florida State University, Tallahassee; *mollywo@rams.colostate.edu*

Genetic and developmental drivers of convergent ear loss in toads

A number of genetic, development, and selection factors can contribute to the evolution of convergent traits. So often, we focus on selection pressures as the driver of convergence; however, many anuran (frog and toad) species have independently evolved earlessness, the lack of a tympanic middle ear, despite limited evidence that shared selection pressures contribute to these independent middle ear losses. The tympanic middle ear normally transmits airborne sound from the environment to their inner ear sensory cells, making the middle ear's loss puzzling given the importance of acoustic communication in most anuran mating systems. Here we investigate the genomic changes, developmental biases, and potential selection pressures affecting the lability of middle ear structures in the true toad family (Bufonidae). We characterized genomic changes across independent evolutionary transitions of ears to identify shared mutations and selection pressures on genes that pattern the middle ears. The minor differences between eared and earless skulls indicate that the middle ear is lost without change to other developmentally or genetically linked skull features. We have also shown that the middle ear forms very late in the development of toads despite high frequency sensory costs. I interpret these results in light of known natural history data for earless toad species and discuss interactions between selection and developmental processes in shaping the evolutionary lability of ear structures.

99.1 WONG, JY*; CHAN, BKK; CHAN, KYK; Academia Sinica, Taiwan, Hong Kong University of Science and Technology, Hong Kong; *wongjinyung@gmail.com*

Functional morphology of barnacle nauplii: a meta-analysis of the effect of trophic modes and allometry on larval shape

Barnacles inhabit a wide range of habitats. While evolution and functional morphology of the sessile adults are well studied, little attention have been given to that of the planktonic larval stages, especially the nauplius. We performed the first meta-analysis on outlines of barnacle nauplii head shield. A total of 103 species were analyzed with normalized elliptic Fourier analysis. Principal component analysis showed that most species were distributed around the center of a shared morphospace but a few minor groups occupied the periphery and contributed the most to the overall shape variance. The peripheral groups include the lecithotrophic nauplii and the large Lepadidae nauplii with exaggerated morphology. We hypothesize that trophic mode is important in morphological evolution of barnacle nauplii and drives the nauplii to deviate from the 'generalized' shape. To tease apart the effect of allometry on naupliar morphology, we decomposed the overall shape variation into common allometric component (CAC) and residual shape components (RSC). Feeding Lepadidae nauplii separated from the others along CAC, suggesting difference in habitats and/or evolutionary history might have accounted for the difference in size. RSC significantly explained the differentiation between lecithotrophic and planktotrophic nauplii. Visualization of shape changes along first RSC showed a change in length of frontal horns. Such shape change highlights the potential importance of frontal horns in feeding. Future detailed analysis of the function of such feature is much needed for it is unique to barnacle nauplii and used to support monophyly of barnacles.

P2.19 WOODARD, L. W.*; DAME, J.; WACK, C. L.; Chowan University; *lwwoodard0321@chowan.edu*

Salinity stress effects on development and behavior in Xenopus laevis

Sea levels in North Carolina are currently higher than they ever have been and are still rising today (CCSP, 2009). Rising sea levels can increase the salinity levels in nearby freshwater habitats after major storm events. Frogs use these freshwater habitats to lay their eggs. Increases in salinization of these areas act as a stressor and could influence the growth and development, physiology, and behavior of the developing tadpoles. Frogs in Puerto Rico developing in high salinities showed higher mortality, decreased mass, and increased number of developmental abnormalities (Rios-Lopez, 2008). Understanding how stressors, such as increased salinity levels, affect amphibians is of particular importance due to the global amphibian decline. At minimum, a third of the world's amphibian species are listed as threatened. Research to understand the sublethal effects of rising sea levels is important to help conserve this important group of animals. We hypothesize that increased salinity levels will adversely affect the physiology and behavior of developing tadpoles. To test this hypothesis, we exposed African clawed (*Xenopus laevis*) tadpoles to three treatments, which represent naturally occurring salinity levels: freshwater (control; 0 ppt), low salinity (5 ppt), or high salinity (10 ppt). During their development, each week the Gosner stage of development, snout-to-vent length, total length, and mass of each tadpole was measured. Locomotor activity was measured at premetamorphic (growth of trunk and tail, Gosner stage 31), prometamorphic (hindlimb development, Gosner stage 50), and metamorphic (development of forelimbs, Gosner stage 60) stages. We predicted that tadpoles exposed to high saline will have the greatest decline in growth and show the greatest change in locomotor activity compared to the freshwater and low salinity treatments.

P1.4 WOODLEY, SK*; ODONNELL, AF; Duquesne University; *woodleys@duq.edu*

CIRCLE: Connecting Interdisciplinary undergraduate Research with Community-engaged Learning Experiences

In summer of 2016, undergraduates in the Duquesne University Summer Undergraduate Research Program (URP) participated in 2 models of community-engaged learning. The first was a "push-out" model, where URP students translated themes from their research into interactive science activities that they shared with middle-school aged children at a free summer camp offered to children in an economically-challenged Pittsburgh neighborhood. Working in teams, URP students spent about 2 hours per week over 10 weeks preparing for, engaging with, and reflecting on the experience. As measured by retrospective posttests, URP students reported gains in disciplinary understanding and skills, improved attitudes towards community-engaged learning, and felt the experience was important for their scientific growth and reaching their career goals. At the same time, campers were exposed to topics in cell biology, conservation biology, neuroscience, and pain empathy, thereby contributing to the scientific literacy of the campers and inspiring an interest in science. The second model was a "pull-in" model, where high school students from Pittsburgh Public Schools shadowed undergraduate researchers for 25 hours a week for the last 5 weeks of the URP. Undergraduate students who mentored the high schoolers reported gains across the board, in particular in communication skills and improved attitudes towards mentoring high school students. High school students also reported tremendous gains in research skills and attitudes towards science, with gains higher than the national averages for undergraduate students in similar research experiences. Together, these results demonstrate the substantial benefits of including meaningful science-based community-engagement, fully integrated into the students' research activities, as part of the undergraduate research program.

145.1 WOODLEY, SK*; FREEMAN, PE; RICKETTS, TD; Duquesne University, Carnegie Mellon University; *woodleys@duq.edu*

Innovations in a Physiology Laboratory Course: Combining Novel Research and Service-Learning to Address a Community-Based Problem

Course-based undergraduate research experiences (CUREs) are increasing in popularity due to the large number of students that can participate and the ensuing learning gains. Although novel research experiments are often integral to CUREs, service-learning typically is not. Starting in 2013, I incorporated novel research and service-learning into a junior-level physiology laboratory course. The novel research experiments and the service-learning were tied to the theme of water quality, a community-based problem. I assessed student learning with surveys, critical thinking assessment tests, and student reflections. Compared to previous years, students reported widespread gains such as increased understanding of science, how scientists think, skill in science writing, and self-confidence. Many of the gains exceeded those of students nationwide, as well as those of students participating in a summer undergraduate research program. The service resulted in better scientific outreach skills, and students recognized the need to give back to the community by sharing their scientific expertise. Together, these results indicate the power of incorporating high-impact practices into a physiology laboratory course to foster both scientific development and civic engagement in our students.

125.5 WOODS, H. A.*; LANE, S. J.; TOBALSKE, B. W.; SHISHIDO, C. M.; MORAN, A. L.; WOODS, Arthur; Univ. of Montana, Univ. of Hawai'i at Mānoa; *art.woods@mso.umt.edu*

Oxygen-Dependent Limits to Body Size in Giant Sea Spiders

Compared to their temperate and tropical relatives, polar marine taxa often reach unusually large body sizes. This phenomenon, known as polar gigantism may be explained by the oxygen hypothesis of Chapelle & Peck (1999, Nature), which states that, in polar conditions, high oxygen availability and low metabolic rates allow larger body sizes. We tested the oxygen hypothesis using sea spiders (pycnogonids), which are small-bodied in temperate regions but reach enormous sizes in polar regions and at great depths. Using temperate and Antarctic species (n = 14 species, varying from 2 mg to 12 g wet weight), we measured the scaling relationships of key aspects of oxygen consumption and transport, including metabolic rate, cuticular conductance, levels of oxygen in the blood, and rates of internal circulation. To integrate these data, we developed a mathematical model describing the radial transport of oxygen from the environment into the tissues. The model accurately predicted the observed concentrations of internal oxygen, which was significantly lower in the largest-bodied Antarctic species > 1 g). Using the established scaling relationships to project the model out to still larger body sizes, we showed that even modestly larger individuals would not obtain sufficient oxygen in the Antarctic, demonstrating that the largest Antarctic taxa are approaching an oxygen-based limit to body size. Additional model simulations suggest even smaller maximum sides at warmer temperatures, which may explain the observed global gradients in pycnogonid body size. NSF PLR-1341485.

P1.285 WOODY, CA*; STINSON, CM; DEBAN, SM; University of South Florida; *cwoody@mail.usf.edu*

Elastic recoil mechanism in the tongue-projection of the gold-striped salamander, Chioglossa lusitanica

Salamanders often use tongue projection to feed on land. Most plethodontid salamanders possess a high-powered, thermally robust, ballistic tongue-projection mechanism in which collagen aponeuroses within the projector muscles store elastic potential energy. Elastic storage allows projection performance to exceed that possible with muscle alone. *Chioglossa lusitanica* has a feeding morphology that is convergent with that of plethodontids and divergent from that of other salamanders in the Salamandridae. Tongue projection is also more elaborate in this species compared to other salamanders. During tongue projection elongate radials rotate about the projecting basibranchial, carrying a sticky tongue pad towards the prey. Using high-speed videography, kinematics, and inverse dynamic analyses, we examined this elaborate tongue projection at a range of temperatures to determine if elastic-recoil mechanisms similar to those in plethodontids could also be used in this distantly related taxon. During both tongue projection and radial rotation, *Chioglossa* showed evidence of an elastic mechanism. Power outputs for tongue projection exceeded 4000 W/kg, while radial rotation often reached over 2000 W/kg. Although power outputs of over 1000 W/kg were still observed over a 10-degree temperature difference, there were decreases in both components of projection performance as temperature decreased. Histological sections of the projector muscles showed the presence of collagen aponeuroses similar to those seen in plethodontid salamanders, which may be the location of elastic energy storage. These results suggest convergent evolution of elastic recoil in *Chioglossa* and plethodontids used for high-powered tongue projection.

85.7 WORD, KW*; WINGFIELD, JC; Univ. of California, Davis; *krlizars@ucdavis.edu*

A Bird's Eye View of Allostasis: Cues, Error, and Variability in the Decision to Respond

The model of allostasis proposes that energy balance plays a key role in determining glucocorticoid physiology. It has been proposed that glucocorticoid levels are most likely regulated based on an individual's proximity to energetic crisis, identified as the Perturbation Resistance Potential (PRP). In the model of allostatic load, this is quantified as the difference between available resources and all sources of allostatic load, Eg - (Ee + Ei + Eo). The pattern of responsiveness to PRP - whether change occurs gradually or abruptly through spikes in hormone levels - may vary and has specific implications for the activation of mineralocorticoid vs glucocorticoid-type receptors. The PRP is a difficult quantity to measure - particularly for an animal. Here, we examine the variety of cues that animals may use to inform them about the status of their PRP and probability of energetic crisis. We consider elevation in glucocorticoid hormones as an endocrine "decision," and consider error management strategies in evaluating responsiveness to cues that may reflect or predict an impending energetic crisis. The potential for differential receptor activation as well as further integrative "decisions" to determine diverse and sometimes contradictory effects of receptor activation is also important to the consideration of error management. This perspective offers insight into the basis of intra- and inter-individual variability in responsiveness, and also opens an avenue towards improving compatibility of the allostasis model with more classical and biomedical views on "stress."

P3.110 WORKING, CL*; SINGH, KS; RUSSELL , ID; GAMBOA, DA; SMITH, JE; Biology Dept., Mills College, Oakland, California 94613, Biology, Mills College; *jesmith@mills.edu*

Social mechanisms shaping individual differences in ectoparasite loads of free-living ground squirrels

Social animals face trade-offs between the costs and benefits of group living. Parasite transmission is a widely-recognized cost of sociality because hosts often suffer from dual costs of parasites acting as stressors and/or vectors for disease. Despite these important fitness consequences, little is known about the social mechanisms facilitating the spread of ectoparasites from one individual to another in wildlife populations. Here, we studied the spread of fleas across free-living California ground squirrels, *Otospermophilus beecheyi*. *O. beecheyi* forage and socialize above ground, but seek refuge from predators in underground burrows. Importantly, there are documented cases of the fleas found on *O. beecheyi* carrying the bacterium, *Yersinia pestis*, the causative agent of plague. Thus, revealing modes of flea transmission in this species has important implications for the study of social evolution as well as for management of zoonotic diseases. In the field, we regularly live-trapped, marked and released squirrels at their points of capture. Upon its first capture of each week, we systematically combed each individual squirrel to sample and collect its fleas. Our results reveal consistent, individual differences in mean ectoparasite loads across time beyond those predicted by age and sex. We are currently analyzing the basal "stress" hormones of these individuals. We are also using social network statistics to test two, non-mutually exclusive hypotheses: 1) space-use overlap hypothesis and 2) social transmission hypothesis to determine whether spatial or social interactions best explain individual differences in flea numbers. Taken together, our results will reveal the importance of host traits in shaping parasite and disease networks in wildlife populations.

38.4 WRIGHT, RM*; KENKEL, CD; BAY, LK; MATZ, MV; University of Texas, Austin, Australian Institute of Marine Science; *rachelwright8@gmail.com*

Tradeoffs in a Great Barrier Reef coral, Acropora millepora: can corals adapt to simultaneous stressors?

Corals are currently threatened by a combination of co-occurring stressors brought about by climate change, including warming sea surface temperature, ocean acidification, increasingly frequent disease outbreaks, and storm damage. In order for corals to adapt to this combined challenge at the genetic level, heritable higher tolerance to one stress cannot come at the expense of tolerance to another stress. In other words, corals cannot adapt if genetic tradeoffs among stress tolerances exist. To evaluate the prevalence of such tradeoffs, we exposed replicate fragments of 43 *Acropora millepora* genotypes to five treatments (control, high temperature, low pH, bacterial challenge, combination). *Symbiodinium* loss (bleaching), mortality, and growth were measured as fitness proxies. As expected, heat treatment triggered the most symbiont loss and bacterial challenge caused the most mortality. Encouragingly, we did not find any significant tradeoffs; instead, genotypes that remained healthy under one stressor were more likely to remain healthy under other stressors as well. This result suggests that there are no genetic constraints to coral adaptation to climate change.

P2.97 WRIGHT, RM*; PAGE, CA; MATZ, MV; University of Texas, Austin, Mote Tropical Research Laboratory; *rachelwright8@gmail.com*

Physiological effects of microfragmentation to propagate coral stock for reef restoration

Many endangered boulder corals exhibit dramatically enhanced growth rates upon fragmentation into very small pieces, leading to the idea that fine fragmentation might be the optimal way to create captive coral stock for reef restoration. However, rapid growth could consume all energetic resources and leave the coral with no physiological capacity to meet natural environmental challenges, such as disease or thermal stress. Here, we evaluated the extent of this potential problem in two major reef-building coral species from the Florida Keys: *Montastraea cavernosa* and *Orbicella faveolata*. Five genotypes from each species were fragmented into progressively smaller pieces with surface areas ranging from 30 to ~3 cm2. Corals were maintained in common raceways for four months before final measurements and preservation for physiological analyses. As expected, smaller fragments grew significantly faster than larger fragments ($P < 0.001$). A significant interaction between initial size and species showed that smaller fragments experienced faster growth rates in *O. faveolata* than in *M. cavernosa* ($P = 0.01$). Protein quantification, immune enzymatic assays, and global gene expression analysis of corals from all sizes demonstrates whether physiological capacity to combat stress and disease becomes significantly compromised in rapidly growing fragments compared to slowly growing fragments. The results from this project directly inform coral reef restoration by providing guidelines for rapidly generating coral stock without compromising coral's environmental robustness.

P2.176 WRIGHT, JE*; MISRA, BB; CHEN, S; AVERY, ML; KIMBALL, RT; Univ. of Florida, USDA, APHIS, Wildlife Services, National Wildlife Research Center; *jwright1855@ufl.edu*

Do turkey (Cathartes aura) and black (Coragyps atratus) vultures have odor signatures that could be used for social communication?

Although initially thought to be unimportant, in recent years, use of olfaction by some avian species has been well established for many activities such as foraging, mating and navigation. Furthermore, some bird species are able to recognize other birds by odor. Turkey vultures (*Cathartes aura*) are known to use olfaction for foraging while closely related black vultures (*Coragyps atratus*) are not thought to forage using olfaction though they have relatively large olfactory bulbs. However, black vultures are considered more social than turkey vultures, suggesting that black vultures may use olfaction to detect social cues. If so, we would expect black vultures to exhibit high levels of individual variability in putative social cues, and/or clear differences between males and females. If turkey vulture olfaction is primarily for foraging, we might expect turkey vultures to exhibit little individual variation and/or sex differences. We analyzed extracts representing uropygial gland (UG) secretions and feathers, both hypothesized to exhibit social odor cues in other bird species, using GCMS to identify the chemical make-up of these social odor cues. Our results indicate that robust differences in chemical make-up exist between feather and UG sources. No chemicals unique to one species or sex were found and chemicals overlapped to a large extent at this level of analysis; however, ordination analysis revealed a reduced, although detectable difference in chemical make-up between both species and sex. Additionally, chemical signatures appear to be highly variable among individuals in both species which may impart odor fingerprints that could potentially be used for individual recognition.

22.6 WRIGHT, TF*; HARA, E; WHITNEY, O; LUCERO, E; ARAYA-SALAS, M; New Mexico State University; *wright@nmsu.edu*

Hardwired for plasticity? The role of FoxP2 in maintaining vocal plasticity in the budgerigar

Vocal learning is a complex trait that is expressed differently across different taxa. While many of the best-studied species are close-ended learners with limited juvenile critical periods for learning, others are open-ended learners with plastic repertoires that can be modified later in life. Budgerigars, *Melopsittacus undulatus*, are an extreme example of open-ended learners; in this parrot species both sexes have a repertoire of multiple contact call types that continually change throughout adulthood to match the call types of social associates. However, the neural and genetic mechanisms that underlie this persistent plasticity are currently unknown. Here we investigated the activity of *FoxP2*, a gene associated with vocal learning in both humans and songbirds. We placed budgerigars in a social paradigm in which they were either maintained in stable social groups or moved into groups with novel social associates. We then measured changes in the contact call repertoire and levels of *FoxP2* mRNA and protein in the parrot vocal learning center MMSt. Birds in both treatments changed their contact calls over the two days between baseline and post-move recording, but birds that moved into novel groups showed greater vocal plasticity than those that remained in stable groups. *FoxP2* levels were downregulated in the MMSt relative to the surrounding striatum in both groups, but there was no difference in the degree of downregulation between the two treatments one day post-move. These results are consistent with the hypothesis that the downregulation of *FoxP2* in the MMSt permits the persistent vocal plasticity observed in adult budgerigars across a variety of social contexts.

P2.83 WROBEL, ER*; MOLINA, E; KHAN, NY; PUSCH, EA; NAVARA, KJ; MENDONCA, MT; University of Georgia, Auburn University, Auburn University ; *ewrobel@uga.edu*

Quantification of ARs in the germinal disc region of the hen

Female birds can skew the sex ratio of their offspring in response to environmental and social conditions. However, the mechanism by which sex ratio adjustment occurs is unknown. In multiple avian species, including chickens, testosterone (T) treatment results in male-biased sex ratios, with previous work suggesting that T may be acting on the germinal disk (GD) to determine which sex chromosome is retained in the oocyte. Recently, it has been shown that androgen receptors (ARs) are located in the GD region of the F1 follicles, which presents a pathway that T may act on to influence offspring sex. We hypothesized that, if testosterone acts directly on the GD to influence offspring sex, then AR expression in the GD should be highest at the time of meiotic segregation (3-5h prior to ovulation) relative to other times during the ovulatory cycle. To test this, oviposition times for 400 hens were monitored 5 times per day for five weeks, which allowed us to determine which hens were laying the most consistently. Then, F1 follicles were collected from 40 hens at the time of meiotic segregation and from another 40 hens at a point well before meiotic segregation for quantification of AR expression via quantitative real-time PCR. This allowed us to determine whether AR expression is highest on the GD just prior to meiotic segregation. This study may provide critical insight into the potential hormonal mechanisms that underlie sex ratio adjustment in birds.

140.1 WU, J*; HA, S; KIM, G; DHANUSHA , S; BRACCINI, S; HU, D; Gatech, Atlanta, Zoo Atlanta, Atlanta; *791396787@qq.com*
Elephant Trunk Forms Joints to Better Grip Objects
The boneless elephant trunk is the elephant's most versatile appendage, enabling it to grab objects as heavy as a log or as a small as a peanut. We measure the contact force that elephants apply to piles of vegetables as they squeeze them into a pile and pick them up. We find that elephants can be surprisingly gentle. Specifically, they push down on objects with only 5 percent of their trunk weight, less than half the weight that blindfolded humans apply to objects. This ability is made possible by the elephant forming joints with its trunk. The joint separates the trunk into two sections, the latter of which pushes down on objects purely with its self-weight. Elephants change the location of the joint accordingly to modify the downward force necessary to gather the food particles together. This work may inspire ways to control soft robotic actuators.

69.4 WU, L*; LAMBERT, JD; HIEBERT, LS; MASLAKOVA , SA; KLANN, M; SEAVER , EC; PASSAMANECK, YJ; BASTIN, BR; CHNEIDER, SQ; Univ. of Rochester, Univ. of Oregon, Univ. of Oregon, Univ. of Florida, Univ. of Hawaii, Iowa State Univ.; *longjunwu@rochester.edu*
Spiralian-specific genes in ciliary bands
Lineage-specific genes-those conserved within one group but absent in outgroups-may contribute to novelty. Studies of these genes are rare, especially those restricted to ancient clades. We bioinformatically identified genes specific to the large superphyletic clade Spiralia, and examined their expression in a mollusc. Strikingly, two of 20 genes were specifically expressed in the ciliary band of the larva. Many spiralians have prominent ciliary bands, suggesting that such bands are an important spiralian character; however, it is not clear whether these bands are homologous, or why they are so prevalent in this group. We then carried out a comparative survey across the Spiralia, examining one or both of these genes in two polychaete annelids, two nemerteans, a brachiopod, a phoronid and a rotifer. In most taxa, the genes were specifically expressed in the major ciliary bands in the larva (annelids, phoronid, and brachiopod). In the case of the rotifer, the gene studied was present in the corona, a prominent ciliary band in the adult, and in the case of the phoronid, the gene studied was expressed in the developing lophophore, an adult ciliary feeding structure found in several spiralian groups. Nemerteans are thought to have secondarily derived ciliary bands, and in a representative of this group, the gene studied was expressed in association with, but not specific to, the primary ciliary bands. We are currently testing these genes' functions. These are the first genetic data that potentially unite the diverse ciliary structures of spiralians, and suggest roles in spiralian-specific aspects of ciliary biology. This provides a rare example of lineage-specific genes participating in a key trait in an ancient metazoan clade.

P2.103 WURTZ, MC*; CUSSEN, VA; CORNELIUS, JM; Eastern Michigan University, University of California, Davis; *mwurtz@emich.edu*
The effects of elevated corticosterone on social learning in red crossbills (Loxia curvirostra)
Foraging success can limit fitness if resources are unpredictable and strongly favor those individuals that learn socially. Red crossbills specialize on temporally and spatially unpredictable conifer seeds and use public information to cope with the unpredictability. When crossbills fail to locate sufficient seed, they make irruptive migrations and must survive on novel food sources. In addition to adopting new foraging techniques, crossbills also respond to food reduction with physiological adaptations. For example, they respond to food reduction by elevating stress hormones and increasing activity in laboratory settings. Corticosterone (CORT) is a stress hormone that alters behavior and increases in response to metabolic demand and physical or psychological stressors, including food shortages and unpredictable environments. We explore the relationships between CORT and social learning in red crossbills using a two action model to tease apart learning through imitation. Imitative learning in red crossbills will be discussed along with how corticosterone mediates behavior (i.e., activity and ability to learn) during challenging conditions.

P3.170 YACOO, KE; DAYFIELD, DJ; MAXWELL, DN; BARAWI, KM; ABRAHAM, NK; EVANS, KE; BELANGER, RM*; ROBERTS-KIRCHHOFF, ES; University of Detroit Mercy, Marygrove College; *belangra@udmercy.edu*
Examining Atrazine Accumulation and Histological Changes in the Hepatopancreas of Crayfish Post-Exposure
Many herbicides, including atrazine (ATR), are known to have long-term adverse effects on aquatic organisms. These include death, decreased fecundity, DNA damage and changes in behavior and physiology. It is of interest to quantify how ATR accumulates in aquatic organisms in order to assess long-term cellular effects and if recovery is possible. We developed a method to quantify the amount of ATR in the hepatopancreas of the virile crayfish (*Orconectes virilis*). Crayfish were treated at different environmentally-relevant (80 and 300 ppb) and control concentrations 0 ppb (negative control) and 1000 ppb ATR (positive control) for 15 days. Following exposure, the hepatopancreas was removed. ATR was extracted from the hepatopancreas using a quick, easy, cheap and effective (QuEChERS) method. Following the extraction, the ATR recovery was analyzed using liquid chromatography-mass spectroscopy (LC-MS). The LC-MS method allows for the analysis of ATR and its metabolites. A standard solution of ATR was prepared and analyzed using LC-MS. The amount of ATR in the tissue was determined by using the standard curve of ATR (range - 5-5000 ppb). Additionally, histological changes in the hepatopancreas, including increased vacuolization, were visualized following sectioning and staining with hematoxylin and eosin. Increases in hepatopancreatic vacuoles may indicate that ATR is actively being metabolized and removed from the body.

52.6 YANAGITSURU, YR*; AKANYETI, O; LIAO, JC; Whitney Laboratory for Marine Bioscience; *yuzo.yanagitsuru@gmail.com*

Head Shape in Fishes Influences the Detection of Vortices

Fishes exhibit an enormous diversity of head shapes, which could have important consequences for how hydrodynamic signals are detected. To explore how head shape affects flow detection by the lateral line canal system, we sought to determine how head width affects vortex detection. We 3D printed fish head models of different widths (1.9, 5.8, 9.3 cm), each with 7 pores arranged horizontally with equidistant spacing (1 cm) starting from the snout. We placed a pressure transducer in each pore and exposed the models to different size vortices, which we generated by placing stationary cylinders of varying diameters (1.3, 2.5, 5 cm) in flow. By measuring signal-to-noise ratios (SNRs), we found a correlation between head width and the SNR detected for each vortex size. Skinny (S) heads detected small vortices better than intermediate (I) and wide (W) heads (S: 31.4±0.9%, I: 20.3±0.9%, W: 17.2±1.1%). Skinny and intermediate heads detected medium vortices similarly, and better than wide heads (S: 36.9±0.4%, I: 35.3±0.5%, W: 28.6±0.7%), whereas intermediate and wide heads detected large vortices better than skinny heads (S: 36.7±0.5%, I: 42.7±0.7%, W: 39.9±0.7%). We also varied flow speeds and found that detection of small and medium vortices did not depend on flow speed for skinny heads but that slower flow enhanced detection for intermediate and wide heads. For all head shapes faster flow enhanced detection of large vortices. We also varied the downstream distance of the heads from the cylinder but found no significant effect. Our results suggest that head width can act as a passive filter for the detection of different sized vortices, which may have implications for the types of hydrodynamic signals available to fishes that vary in head morphology.

P1.96 YANG, H*; HOCHBERG, A; DHIMITRI, S; HOCHBERG, R; WALSH, E; WALLACE, R; Univ. of Massachusetts, Lowell, Univ. of Massachusetts, Boston, Univ. of Texas, El Paso, Ripon College, WI; *Hui_Yang@student.uml.edu*

Getting a New Head in Life: the Non-homology of the Rotifer Corona and Infundibulum

Rotifera *sensu stricto* (minus Acanthocephala) is a well-defined lineage with several autapomorphic characters that include a ciliated corona, muscular pharynx with hardened jaws (trophi), and syncytial epidermis with intracytoplasmic lamina. The corona is often the most recognizable feature in rotifers as it comprises two circumapical rings of cilia at the anterior end, often elaborated into a series of lobes or wheel-like structures that function in locomotion and feeding. Despite the vast diversity of coronal shapes and sizes, the corona is hypothesized to be homologous throughout the phylum. However, a select clade of rotifers, the Collothecaceae (Monogononta: Superorder Gnesiotrocha), consists of species that have a corona as larvae but lack one as an adult. When larvae settle, they undergo a remarkable metamorphosis wherein the corona is completely replaced by an entirely new head called the infundibulum. The infundibulum is cup-shaped and often adorned with setae and/or tentacles. Despite the obvious differences between the corona and infundibulum, both structures are often considered homologous in the taxonomic literature, and the infundibulum is hypothesized to be a derived form of corona. However, recent results call this hypothesis into question. Here we present evidence to suggest that the infundibulum is unique to species of Collothecaceae and not homologous with the corona. We use data derived from studies of larval and adult morphology and development to show that the infundibulum is a derivative of the larval foregut and not the larval corona.

25.6 YANG, H*; HOCHBERG, R; Univ. of Massachusetts, Lowell; *Hui_Yang@student.uml.edu*

The Ultrastructure of Rotifer Secretion Tubes

Rotifers are some of the most common aquatic invertebrates in freshwater systems. Most rotifers are planktonic and easily recognized by their ciliated corona and hardened jaws called trophi, but many species in the superorder Gnesiotrocha are sessile on submerged vegetation and defined in part by their abilities to produce tubular sheaths around their bodies. These tubes are hypothesized to have defensive functions and are present in a variety of morphologies as gelatinous sheaths, hardened pipe-like secretions, and tubes of pseudofecal pellets. The morphology of the tubes appears to be independent of phylogeny as some closely related species produce entirely different tube types, while distantly related species may produce morphologically identical tubes. In an effort to gain a better understanding of tube diversity, we explored the ultrastructure of various tubes by scanning and transmission electron microscopy. We find that most gelatinous tubes (e.g., species of the distantly related genera *Conochilus* and *Stephanoceros*) share a similar ultrastructure that consists of a network of fine electron-dense secretions that probably function to hold an aqueous medium in place. These matrices appear to be derived from the pedal glands of the foot. Other species such as those of some *Floscularia* produce pseudofecal pellets and layer them atop a thin gelatinous membrane that is similar in ultrastructure to the gelatinous tubes. Alternatively, the hardened pipe-like matrices present in species of *Limnias* appear to derived from trunk glands, and consist of a homogeneous opaque material that is devoid of any gelationus matrix. The widespread distribution of gelatinous matrices produced by pedal glands points to their early evolution and one that may define the sessile Gnesiotrocha, while the hardened matrices of Limnias appears to be an independently derived secretion.

P1.226 YANG, X*; WANG, Y; KENALEY, CP; WAINWRIGHT, DK; LIU, H; GUAN, J; WEN, L; Beihang University, Harvard University, Harvard University; *liwen@buaa.edu.cn*

The Contribution of Soft Tissue and Rigid Spinules to the Adhesive Ability of Remoras (Echeneis Naucrates)

Live remora can generate anisotropic friction force while attaching to a diversity of biological and non-biological surfaces by using spinule-covered lamellar plates in their disc interior. In this study, we used µCT, ESEM and DMA (dynamic thermomechanical analysis) to investigate the morphological and mechanical properties of the preserved remora adhesive disc. The kinematic motion of the disc lamellae when live remoras slide on the glass surface was analyzed through synchronized ventral and lateral high-speed images. Remoras push both the soft-tissue surrounding the lamellae and the rigid spinules against or away from the glass during attachment. To understand the effect of the rigid spinules and lamellae soft tissue on the frictional force during remora attachment, we extracted spinules from a remora specimen and glued them on the rotatable, synthetic lamellae in a bio-robotic remora adhesive disc. We then investigated the influence of the lamellae pitch angle and surface roughness on the frictional forces of the bio-robotic prototype both with and without the biological spinules. The results show that on surface of roughness less than 20µm, the soft tissues rather than the spinules play a dominant role in regulating the friction while changing the lamellae pitching angle. However, on biological shark skin and surface with a roughness of 200µm, the spinules play a more significant role than the soft tissues. Our findings suggest that the rigid spinules and the soft tissues enveloping the rigid skeletons of lamellae work in concert to tune friction during remora attachment on different surfaces.

S2.1 YAP, KN*; SEROTA, M.W.; WILLIAMS, T.D.; Simon Fraser University; *knyap@sfu.ca*

The physiology of exercise in free-living animals: What can we learn from current model systems?

Many behaviours crucial for survival and reproductive success, including migration, foraging, and escaping from predators, involve elevated levels of activity or "workload". It seems intuitive that individuals with higher "capacity" for, or tolerance of the costs of, activity or workload will have higher fitness but does increased physical activity (exercise) enhance athletic capacity in free-living animals? Although there has been considerable interest in the physiological mechanisms that underpin individual variation in exercise performance, to date, much work on the physiology of exercise has been conducted using captive animals in laboratory settings that are often quite removed from the animal's ecology. We will review current, laboratory-based, model systems for exercise to address the question of whether these can inform us about common physiological markers of elevated levels of activity, or the physiological costs of high workload, that might provide relevant 'targets' for mechanistic analysis of routine activities in free-living animals. We will also discuss particular caveats for interpretation of results from laboratory-based systems. Specifically, we will consider a) how physiological responses might be influenced by the nature of exercise, b) resource acquisition and food availability, in the context of routine activities in free-living animals, and c) effects of high workload associated with lab systems of exercise on proxies of fitness such as reproduction. We will conclude by considering whether we need to develop new, more ecologically-realistic models of exercise in the laboratory and we will describe preliminary results on physiological responses to 'training' and 'exercise' in zebra finches (*Taeniopygia guttata*) where we have experimentally manipulated foraging effort.

50.6 YAP, KN*; DICK, M.F.; GUGLIELMO, C.G.; WILLIAMS, T.D.; Simon Fraser University, University of Western Ontario; *knyap@sfu.ca*

Effects of experimental manipulation of hematocrit on flight performance

Migratory birds increase hematocrit (Hct) prior to initiating long distance flight, presumably to increase blood oxygen carrying capacity to sustain high intensity exercise. Despite widely held assumptions that Hct is a key determinant of aerobic capacity and exercise performance, their relationship has not often been tested rigorously and results to date are mixed. Furthermore, it is known that although passerines spend the majority of time flying at low altitude (<800m) during migratory flight, they do sometimes fly at higher altitudes depending on winds and weather (up to 4000m). However, most studies investigating physiology of migration have been conducted at low altitude and have largely ignored the transient but potentially important altitude component. To examine the effects of experimental manipulation of Hct on flight performance, we treated yellow-rumped warblers (*Setophaga coronata*) with avian erythropoietin (EPO), erythropoietin antibody (anti-EPO) and saline and assessed flight performance with wind tunnel flights. We also conducted short altitude challenges using a hypobaric wind tunnel to look at effects of EPO and anti-EPO on performance and physiological response to elevated altitude. We collected blood samples upon completion of each flight for Hct, blood glucose and oxidative stress measurements. Preliminary data suggest that while EPO-treated birds performed marginally better than anti-EPO and saline treated birds during endurance flight at low altitude, anti-EPO treated birds were better able to sustain flights at higher altitudes than saline and EPO treated birds. We also observed increased glucose and decreased Hct in response to flight at altitude, regardless of treatment. Assessment of oxidative stress will be also be reported on as a potential physiological costs of endurance flight.

16.2 YAWAR, A*; KORPAS, LM; LUGO-BOLANOS, M; MANDRE, S; VENKADESAN, M; Yale University, New Haven, CT, Brown University, Providence, RI, Brown University, Providence, RI; *ali.yawar@yale.edu*

Bending-stretching coupling in the human foot: Role of the transverse arch

The human foot acts as an elastic interface between the body and ground, and must be sufficiently stiff to propel the body while still maintaining its form. Compared with healthy and arched human feet, the flat feet of those with collapsed arches or other primates such as the chimpanzee are softer and bend severely at the midfoot. Recent work hypothesizes that the transverse arch is the dominant contributor to the foot's stiffness [1]; two to three-fold higher than the contribution from the longitudinal arch and longitudinally oriented soft tissues including the plantar fascia. A key prediction of this hypothesis is that the distal metatarsal heads splay apart when the forefoot is loaded, and therefore greater stiffness of distal transverse ligaments implies greater foot stiffness. To test this, we experimentally estimated the foot stiffness of human subjects and quantified the effect of externally stiffening the distal metatarsal heads using elastic tape. Foot stiffness was estimated by applying external loads to bend the foot, and measuring the resultant deformation of the arch by tracking the height of the navicular. The estimated stiffness increases by a factor of 2.06±1.98 (mean ± std, N=7) upon reinforcing the metatarsal heads in the transverse direction using elastic tape. These results with healthy human subjects are the first direct evidence for the role of the transverse arch, and also suggest therapeutic strategies for humans that suffer from collapsed arches. 1. Mandre, S., M. Dias, D. Singh, M. M. Bandi, and M. Venkadesan. "Evolution of the transverse arch made the human foot stiffer." In Integrative and Comparative Biology, v56:E136. 2016.

P3.217 YE, D*; GIBSON, JC; SUAREZ, AV; University of Illinois at Urbana-Champaign; *dajiaye2@illinois.edu*

Jump mechanics in the ant Gigantiops destructor (Hymenoptera: Formicidae)

The ability to jump is rare among ants. *Gigantiops destructor* is well known for its jumping abilities, however, few studies have been done on jump kinematics in this ant. Previous research revealed that *G. destructor* begins its jump by rotating its abdomen and hind legs forward as it takes off, which possibly provides thrust or stabilizes rotational momentum. We aimed to obtain a detailed understanding of the mechanics behind *G. destructor*'s jumping behavior. We used high speed video to record *G. destructor* jumping between two inclines with a 2 cm gap between them. To analyze the function of abdominal rotation in jumping behavior, we anesthetized ants after filming them jumping and applied glue to their abdomen-petiole and petiole-thorax joints, preventing their abdomens from rotating during future jumps. Our results suggest that abdominal rotation is key for stability during jumps; ants tend to lose control of their rotational momentum during jumps when their abdomens are prevented from moving. Takeoff velocity is not affected by restricting the abdomen. Future research will include recording additional individuals to examine the kinematics of jumping behavior in a variety of contexts in relation to foraging and escape.

41.2 YEATON, IJ*; ROSS, SD; SOCHA, JJ; Virginia Tech; *iyeaton@vt.edu*

The kinematics and stability of flying snakes during transient glides

Flying snakes (*Chrysopelea*) uniquely glide using aerial undulation. However, the functional implications of aerial undulation are unknown, as undulation may influence performance by increasing the surface area perpendicular to the flow, and enhance stability by redistributing aerodynamic moments. Here, we combine new kinematic measurements of gliding snakes with reduced-order modeling to determine the effect of aerial undulation on glide performance and stability. We recorded glides originating from a height of 8.2 m in a large indoor arena at Virginia Tech using a 23-camera motion-capture system (179 fps, Qualisys Oqus 500) and two high-speed cameras (500 fps, Photron APX-RS). Of 131 trials, we analyzed 45 trials from 13 individuals in detail. The increased temporal (4X) and spatial (6X) resolutions compared to previous studies enables us to reconstruct the snake's time-varying undulation waveform. Additionally, by assuming an anatomically-relevant limit of vertebral twist, we estimate the local airfoil orientation throughout the body. From these data, we found that the snake employs a large-amplitude out-of-plane movement that is twice the frequency of the lateral wave, which results in changes in airfoil orientation along the body. To test the effects of different waveforms on stability, we used the kinematics results as input into a passive dynamics model combined with theory about glider dynamics. We find that undulation passively stabilizes roll and yaw moments, but overall, the snake is likely unstable in pitch. Additionally, we find large inertial moments about the yaw axis, which suggests that snakes can maneuver by employing a transient bias to the undulation waveform. Supported by NSF 1351322.

P3.231 YEGIAN, AK*; GILLINOV, S; TUCKER, Y; LIEBERMAN, DE; Harvard University, University of Cambridge; *ayegian@fas.harvard.edu*

Why we bend our arms when we run, and evolution of arm proportions in hominins

Humans stereotypically bend their arms at the elbow while running, as opposed to maintaining relatively straight arms during walking. During both walking and running, muscles at the shoulder aid in arm swing while muscles at the elbow resist rotation at the elbow. Using a two-segment biomechanical model of arm swing we hypothesize that there is a tradeoff between the muscle moments at the shoulder and at the elbow: bending the arm reduces the shoulder moment magnitude by reducing rotational inertia of the arm, but increases the elbow moment magnitude by orienting the forearm more perpendicular to destabilizing vertical forces. Experimental data from eleven subjects asked to walk and run with straight and bent arms support the tradeoff hypothesis, and imply that the tradeoff favors straight arms during walking and bent arms during running. In addition, we added mass to the lower arm during both normal walking and normal running and observed a proportionally larger increase in the elbow moment magnitude during running. From an evolutionary perspective, these results suggest that the low Brachial Index (radius to humerus ratio) observed in the genus *Homo* starting with *Homo erectus* can be explained by the evolution of endurance running and the hunter-gatherer lifestyle. Earlier hominins, which are thought to have mostly relied on walking, invariably show higher Brachial Indices than *Homo erectus*. Increased reliance on running by *Homo erectus* likely amplified selection for shorter lower arms, which modern humans still retain.

P3.40 YEN, N/K*; ROUSE, G/W; Scripps Institution of Oceanography, UCSD; *nkyen512@gmail.com*

Phylogeny, biogeography, and systematics of Pacific vent, seep, and whalefall Parougia (Dorvilleidae, Annelida) with 7 new species

The family Dorvilleidae is a well-represented group among annelids associated with chemosynthetic habitats. Seven new *Parougia* species are recognized here from collections at Pacific Ocean whale-falls, hydrothermal vents, and methane seeps. The specimens were studied using morphology and phylogenetic analyses of DNA sequences from mitochondrial and nuclear genes. Currently, there are 11 described *Parougia* species, of which two are associated with vents or seeps: *Parougia wolfi* and *Parougia oregonensis*. *Parougia oregonensis* has previously been recovered as three separate clades based on DNA data. New collections and analysis allow the designation of one of these clades as *P. oregonensis*, with the others as new species. An additional two sympatric sister clades of *Parougia*, also from Oregon, correspond to new species with one widely distributed extending to seeps in Costa Rica. This study also identifies a new West Pacific species sister to the clade that includes *P. oregonensis* and its sibling species. Another new *Parougia* species from the Eastern Pacific margin is sister to *P. wolfi* and these species form a clade that include a further new *Parougia* and previously described *Parougia bermudensis* known from shallow-water woodfalls in the North Atlantic. Several of the new *Parougia* species and previously described species are broadly distributed and capable of inhabiting different chemosynthetic habitats. The dorvilleid genus, *Ophryotrocha* has been highlighted as diversifying in the deep-sea environment. Our results emphasize the hitherto unknown diversity of other taxa such as *Parougia* in these chemosynthetic systems.

17.4 YEUNG, D; WANG, X; HSU, S; LIU , P ; CHENG , B*; CHENG, Bo; The Pennsylvania State University; *buc10@psu.edu*

Flight Mechanics of Landing Maneuvers in Bluebottle Flies

Landing maneuvers on an inverted horizontal surface (or a ceiling) is arguably one of the most difficult aerial maneuvers in flying insects, but received relatively little study. Herein, using high-speed video recordings, we aim to understand the mechanics and control of landing maneuvers in bluebottle flies (Calliphora vomitoria). In the experiment, about 40 flies were introduced into a transparent chamber with a backlit ceiling made of a thin stretched plastic membrane. The landing maneuvers were recorded by triggering three high-speed cameras after startling the flies, when a number of flies attempted to land on the ceiling. Total 40 successful and 20 failed landing maneuvers were recorded. Results show that flies were able to land on the ceiling by performing rapid body rotations, most frequently about pitch axis, but sometimes also about roll and yaw axes. Flight speed, direction and body orientation prior to landing varied significantly among maneuvers, and only with a proper combination of these three parameters, the flies were able to land successfully. The legs of the flies were also employed differently when they landed with different patterns. For example, when approaching the ceiling vertically at high speed, the flies performed large pitch to orient their body upside down and landed with all feet touching the ceiling approximately simultaneously. However, when approaching to the ceiling with a shallow angle or at a low speed, the flies extended their forelegs upward and only performed a relatively small pitch prior to landing; the majority of the pitch occurred after the forefeet had firmly bounded to the ceiling, while the flies swung their body upward and landed. Files were also able to change their wing beat kinematics substantially during the maneuvers.

10.3 YOHE, LR*; ROSENTHAL, H; HOFFMANN, S; DAVALOS, LM; Stony Brook University, Smithtown High School, NYIT College of Osteopathic Medicine; *laurel.yohe@stonybrook.edu*
Birth-Death Dynamics Reveal how Phylogeny and Ecology Shape the Evolution of Mammalian Vomerolfaction
In mammals, social chemical cues are primarily detected by receptors in the vomeronasal organ (VNO), including proteins encoded by a large gene family known as vomeronasal type I receptors, or V1Rs. While vomerolfaction is well conserved due to its role in fitness-related behaviors, several mammalian groups have lost function, including Old World primates, some aquatic mammals, and most bats. Mammals lacking vomerolfaction are thought to exhibit a degraded VNO and pseudogenized V1Rs, but it is unclear whether these losses are related to ecology, phylogeny, or both. To investigate this question, we obtained the V1R profiles from nearly every order of mammal, and estimated the birth and death rates of gene duplication and loss. We also quantified VNO morphology from iodine-stained soft tissue µCT-scans to test how variation in vomeronasal form correlates with the evolution of V1Rs. Our results reveal that the evolutionary history of the mammalian vomerolfaction was complex, with few clear ecological explanations for loss or gain. Many mammalian orders have experienced slowed birth rates of V1R genes, but some of these lineages still possess well-developed VNOs, and retain orthologous receptors shared with distantly related species. This result suggests strong purifying selection on these genes in light of low diversification. Our study demonstrates that vomerolfaction may actually be a crucial sensory system in some species (e.g. bats) in which its function was previously underappreciated, and highlights the importance of incorporating birth-death models and phylogenetic comparative methods to understand the evolutionary history of complex traits, such as sensory systems.

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Successful Predator Evasion by Squid Dependent on Multiple Sensory Modalities throughout Ontogeny
Cephalopods depend on multiple sensory systems for predator detection. In this study we examine the role of two sensory systems, the lateral line analogue and vision, in successful predator evasion of squid throughout ontogeny. Squid *Doryteuthis pealeii* and *Lolliguncula brevis* were recorded using high-speed videography in the presence of natural predators under light and dark conditions with their lateral line analogue intact and ablated via a pharmacological technique. Paralarval squid showed reduced escape responses when ablated, indicating that the lateral line analogue is important for predator detection early in life. Ablated juveniles and adults had lower response times, escape velocities and peak acceleration than non-ablated individuals, indicating that the lateral line analogue enables squid to respond quicker and with more powerful jets to a predator and maximize escape success. Throughout ontogeny, squid oriented themselves anteriorly towards the oncoming predator, maximizing sensory input to the lateral line analogue system and providing better positioning for tail-first escape jetting. Our findings reveal that the lateral line analogue contributes to predator detection and successful escape response at the earliest life stages, and continues to add to successful evasion by aiding visual cues in juvenile and adult squid.

P1.84 YOU MAK, KT*; COLLIN, R; Barnard College, Smithsonian Tropical Research Institute; *kty2104@barnard.edu*
Environmental and Parental Effects on Slipper Snail Larval Growth and Survival
Amidst a rapidly changing climate, it remains important to understand the effects of natural environmental variation. The Bay of Panama experiences wind-driven upwelling during the dry season that is characterized by lower water temperature and higher salinity than the non-upwelling rainy season. Marine organisms that reproduce year round experience both of these conditions, but they may not be equally successful under both conditions. To study larval growth and survival in upwelling and non-upwelling conditions, we used larvae of the intertidal slipper snail, *Crepidula cf. marginalis* . Four environmental treatments were used as a 2x2 cross of high (34ppt) and low (30ppt) salinity with high (30°C) and low (24°C) temperature, which includes upwelling (high salinity, low temperature) and non-upwelling (low salinity, high temperature) conditions. We hypothesized that larval growth would positively correlate with temperature, be unaffected by salinity, and vary with parentage as well as that mortality would vary with parentage. Full-sibling families of larvae were each divided into 4 cups containing 30 larvae placed into each of the 4 treatments. On day 6, the live larvae were counted and preserved for imaging. ANOVA showed salinity, temperature, and parentage all had statistically significant effects on the survival of the larvae to day 6, as well contributing to the effects of interactions with parentage. Environmental conditions did matter for larval survival in our experiment, and the effect of specific environments on survival varied based on parentage. Thus, the significant effects of the environment on larval survival and growth depends heavily on their parentage, suggesting that significant effects of environmental conditions might be masked at a population level.

S10.4 YOUNG, Nathan M; University of California, San Fransico; *nathan.m.young@gmail.com*
Evolutionary integration of the amniote limb
A central question in evolutionary developmental biology is how the remarkable diversity found among distantly related species could be generated by highly conserved developmental systems. In part this paradox reflects our ignorance about the potential for developmental systems to generate novel variation. Limbs are an attractive system for addressing this question for a number of reasons. First, diversity in limb sizes, proportions and associated functions is in contrast to the deep homology in genetic patterning mechanisms shared from fish to birds to mice. Second, limbs are both easily quantified and frequent in the literature, enabling robust comparisons of potential to observed diversity. Third, limbs are serially homologous, enabling comparisons both between limbs (i.e., fore vs. hind) and species. Here I present results from a rich dataset representing >1,400 mammal, avian, and reptile taxa, focusing on patterns of both within and between limb variation. I demonstrate that: (1) within limb proportions are heavily biased such that proximal and distal segments function as tradeoffs while the middle segment is more conservative, a signal that is evident from early in development, and (2) functional dissociation of fore and hind limb is linked to increased diversity in between limb proportions. These under-appreciated patterns of diversity provide crucial clues about the developmental timing and mechanism by which species-specific limb variation is plausibly generated. One possibility is that early patterning contributes to amniote limb diversity via activation-inhibition dynamics, in which case a simple "design rule" found in a range of structures could explain both the generation and limitation of observed phenotypic outcomes. However, whether such a universal morphogenetic rule exists in limbs requires further validation in experimental systems.

84.4 YOUNG, JW*; WOLFE, AN; CHADWELL, BA; Northeast Ohio Medical University, Ohio University; *jwyoung@neomed.edu*
Arboreal Locomotor Performance in Gray Squirrels (Sciurus carolinensis) and New World Monkeys: Implications for Primate Locomotor Evolution
Decades of comparative research have established that the evolution of primate quadrupedalism is intimately tied to arboreality. However, attempts to explain primate synapomorphies as "arboreal adaptations" are hampered by the existence of other mammals that lack such features, but are nonetheless committed arborealists. Here, we test the prediction that primate-like grasping and locomotor kinematics confer a performance advantage relative to other arboreal mammals. We collected high-speed video of gray squirrels crossing broad (5cm) and narrow (2.5cm) diameter poles instrumented with force/torque transducers, and compared these data to matching datasets from similarly-sized New World monkeys - marmosets (*Callithrix jacchus*) and squirrel monkeys (*Saimiri boliviensis*). Squirrels consistently used high-speed bounding and galloping gaits across both substrates, moving significantly faster than either of the primates ($p \leq 0.018$). Given that rolling plane angular momentum was negatively correlated with speed across species ($r = -0.687$, $p < 0.001$), squirrels likely moved quickly to increase lateral stability. When transitioning from the broad to the narrow pole, squirrels consistently required the greatest magnitudes of adjustment (i.e., changes in speed, duty factor, and overall substrate contact duration; squirrel effect sizes: 0.245-0.726; primate effect sizes: 0.026-0.422). Our findings suggest that primate-specific morphology and gait patterns increase stability on narrow substrates, providing empirical evidence for the hypothesis that functional aspects of primate anatomy and gait mechanics evolved in response to selective pressures to increase locomotor performance on narrow arboreal supports. Supported by NSF BCS-1126790.

P1.258 YU, S*; KHANDELWAL, P; GARDNER, H; HEDRICK, T; University of North Carolina at Chapel Hill; *skyu@live.unc.edu*
Continuous Aerodynamic Pitch Perturbation of Hawkmoths
Flying animals must stabilize against environment perturbations from a variety of different sources, including aerodynamic effects such as wind gusts and physical effects such as mechanical contact with the environment or other animals. Many methods of studying perturbation response in flying animals rely on a single, brief perturbation event resulting in small datasets and varying perturbation inputs. Here we use a vortex chamber to apply continuous aerodynamic pitch perturbations to freely-flying hawkmoths (Manduca sexta), recorded with three high-speed cameras. Perturbations were delivered at 3 distinct magnitudes plus a hovering control, magnitudes approximated continuous pitch rotation of approximately 500, 1000 and 1500 degrees/s . We hypothesized that moths would respond to pitch-up perturbation by shifting the average stroke position rearward (and vice-versa for pitch-down perturbations) with approximately symmetric magnitudes, and also change wing orientation in each half-stroke by opposite directions for pitch-up and pitch-down, as suggested by recent momentary collision pitch perturbation experiments. Video data were analyzed using a deep-learning neural network trained to identify 6 landmarks on the moth wings and body. Results generally support our hypotheses, with the average stroke position in particular shifting as expected in the low and medium magnitude perturbations. However, compensation for the largest magnitude perturbation was qualitatively and quantitatively distinct and may reflect a shift to behavioral rather than biomechanical compensation.

P3.56 YUAN, T*; MCCAULEY, DW; YUAN, tian; Univ. of Oklahoma; *tianyuan@ou.edu*
Gliogenesis in Lampreys: Insights into the Evolutionary Emergence of Oligodendrocytes
Evolution of the myelin sheath surrounding neuronal axons was pivotal for the success of vertebrates. This remarkable innovation facilitates increased electrical conductivity along axons, allowing evolution of large body size and enabling animals to both respond rapidly to danger and become successful predators. Myelin is absent in the few remaining basal jawless vertebrates, lampreys and hagfish, suggesting that myelination arose after the divergence of agnathans and gnathostomes. The myelin sheath is formed by elongated and flattened glial cells. In the central nervous system (CNS), the myelin sheath is formed by oligodendrocytes that originate from epithelial cells in the ventral neural tube of most jawed vertebrates (a recent study shows mouse has a small number of oligodendrocytes of dorsal origin), and migrate to the marginal zone dorsally and laterally and myelinating the CNS axons. Since motor neurons and oligodendrocytes both originate along the ventral neural tube, this raises the possibility that oligodendrocytes first evolved to accompany motor axons, facilitating a rapid response to the environment. Our investigation of gliogenesis in a basal vertebrate—the sea lamprey, provides evidence to support this hypothesis. Lampreys possess glial cells in the ventral neural tube that share a similar origin and regulatory mechanism with gnathostome oligodendrocytes. This suggests oligodendrocytes were present in the ancestral vertebrate prior to the myelinating function of glial cells. Instead of being restricted to the CNS as in jawed vertebrates, lamprey oligodendrocytes emerge from the neural tube along with motor axons, suggesting they may have evolved in the ancestral vertebrate to support motor axons both inside and outside the neural tube. After the divergence of agnathan and gnathostome vertebrates, oligodendrocytes were restricted to ensheath the axons in the gnathostome CNS, while Schwann cells evolved to support peripheral neurons.

100.1 ZACHOW, Z*; NOEL, A; HU, DL; Georgia Institute of Technology; *alexis.noel@gatech.edu*
Earwax has properties like paint, enabling self-cleaning
The ear is subject to invaders such as dust, insects, mud and even feces. The secretion of earwax has long been though to protect the ear and remove intruders. We film the motion of the ear canal in humans and measure the rheological properties of earwax of pigs, dogs, cows, and humans. We find that earwax is shear-thinning for all these animals. This ability enables it to cling to the ear in low volumes providing a protective layer to adsorb particles. When large volumes are eventually secreted, the movements of the jaw causes the earwax to flow and fall out of the ear, taking particles with it.

P2.76 ZAJIC, DE*; PODRABSKY, JE; Portland State University; *zajic@pdx.edu*

The role of γ -aminobutyric acid in anoxic and desiccated annual killifish embryos

In most organisms, even brief episodes of low oxygen supply can cause irreparable damages to vital organs, such as the brain and heart. The annual killifish (*Austrofundulus limnaeus*) survives in ephemeral ponds and their embryos have the remarkable ability to tolerate anoxia for months. In addition, *A. limnaeus* must also contend with the seasonal dehydration of their ponds, which they survive through mechanisms that likely impose highly limited gas exchange. We propose that anoxia tolerance is a pre-adaptation that allowed the evolution of dehydration tolerance. Thus, we predict that *A. limnaeus* embryos exposed to dehydrating conditions will show similar responses at the molecular level to embryos exposed to anoxia. When exposed to anoxia, embryos of *A. limnaeus* respond by producing large amounts (> 10mM) of the neurotransmitter γ -aminobutyric acid (GABA). When exposed to desiccation, embryos of *A. limnaeus* also respond by producing significant amounts of GABA, though at a slower rate than when exposed to anoxia. GABA has been found to provide excitatory actions in the developing vertebrate nervous system, but conversely, typically functions as an inhibitory neurotransmitter in adults. We hypothesize that *A. limnaeus* embryos produce GABA as a metabolic end-product during exposures to anoxia, as well as during exposures to desiccation. The high levels of GABA accumulated during anoxia and desiccation in *A. limnaeus* embryos suggests GABA may serve a purpose other than as a neurotransmitter when embryos are under stress.

57.2 ZAMORE, SA*; BOCHICCIO, L; SOCHA, JJ; Virginia Tech , Virginia Tech; *Zamore@vt.edu*

Visual Acuity of Flying Snakes: Behavioral Responses to Optokinetic Stimuli

Flying snakes exhibit numerous behaviors that suggest that they actively control their gliding locomotion. Flying snakes are also characterized by large eyes relative to head size, and a large optic tecum, relative to brain volume. This evidence suggests vision may be a valuable sensory modality, which may be employed to estimate timing and distance of jumps and in-air turns, and to inform landing site choices. However, the performance limits of their sensory systems have not been characterized. Here we ask: what are the spatial and temporal limits of vision in flying snakes? What behaviors are elicited when these snakes are presented visual motion? To investigate these questions, we placed *Chrysopelea ornata* and *C. paradisi* in an optomotor drum and presented a vertical black-and-white grating of varying spatial densities (1.7 - 125 cycles per degree) that rotated at varying speeds (3-48 deg/s) with constant luminance. Using tracked head position, we calculated behavioral kinematics, including head direction, angular rotation, and head displacement. We found that freely moving snakes present a series of behaviors including nystagmus (smooth pursuit and snap back), head-tracking (smooth pursuit only), head wagging (lateral oscillatory translations), targeting (fast approach to a single dark bar), chasing (moving with the stimulus around the drum), and climbing. Based on preliminary data, the ratios of these behaviors change with stimulus speed. Both species are capable of head-tracking a stimulus up to about 2.1 cpd, and were observed chasing stimuli rotating at 48 deg/s, producing the equivalent flicker speed of about 99 Hz. These data suggest that flying snakes possess spatial acuity and visual processing speeds that could be advantageous for landing site selection and in-air control.

45.2 ZANI, P.A.*; THOMAS, A.A.; Univ. Wisconsin-Stevens Point; *pzani@uwsp.edu*

Daily emergence in crevice-dwelling lizards during winter is related to temperature, not light

Numerous investigations of the cues for daily and seasonal emergence in reptiles, including those from our lab using side-blotched lizards, have implicated temperature as the primary cue for activity. However, in the field thermal cues are typically confounded by potential photic cues because warm days for emergence are also typically bright, sunny days. Therefore, we performed a laboratory experiment designed to separate the effects of heat and light on the daily activity of side-blotched lizards acclimatized to winter conditions. Lizard emergence correlated with temperature regardless of whether lighting conditions were bright or dim. That is, the timing of daily emergence in the lab supports the role of thermal cues for activity, but failed to reveal any role of photic cues on activity.

P1.115 ZEB, AJ*; PAYNE, AA; JOHNSON, MA; Trinity University; *azeb@trinity.edu*

The Evolution of Social Behavior and Neuromuscular Junctions in Caribbean Anole Lizards

Signals are relayed from an animal's nervous system to its muscles via neurotransmitters, chemicals that are released from a motoneuron, travel across the neuromuscular junction (NMJ), and interact with receptors in the muscle fibers. NMJs are a critical component of muscular contraction, and thus animal behavior. But, does NMJ size vary in association with the behavioral use of a muscle? Here, we test the hypothesis that species that use a muscle frequently evolved larger NMJs in that muscle. We studied 10 *Anolis* lizard species and their use of two muscles: the ceratohyoid (CH), which controls the movement of the dewlap, a throat fan used in courtship and aggressive displays; and the retractor penis magnus (RPM), the muscle that controls movement of the hemipenes during copulation. We collected field observational data for each species to determine the frequency of dewlap display and copulation. Then, we dissected the CH and RPM muscles from each species and stained them for acetylcholinesterase, an enzyme that breaks down the neurotransmitter acetylcholine and is only found in the NMJ, to measure the cross-sectional area and major and minor axes of the NMJs. Larger measurements indicate a broader area of connection between the motoneuron and muscle fiber. Our results show high variation in NMJ size in both the CH and RPM muscles among species, and this variation is not associated with lizard body size or the size of the structures these muscles control. The variation in the RPM muscle, however, is positively associated with the frequency of copulation, and NMJs in the CH (a muscle used every few minutes) are much larger than NMJs in the RPM (a muscle used every few days). This study is among the first of its kind to use a comparative approach to analyze NMJ size across species.

24.4 ZENG, Y.*; CREWS, S.; Univ. of California, Merced, California Academy of Sciences; *yzeng7@ucmerced.edu*

Dynamic leg deformations drive omnidirectional strike maneuvers in flat spiders

Legged animals maneuver by generating bilaterally asymmetric ground reaction forces. Here, we show that the flattie spiders (Selenopidae), a group of ambush predators, perform rapid reorientations when striking prey, exhibiting the fastest turning maneuvers ever documented in legged animals. This maneuver capability allows them to strike toward any direction within an approximate five-body-length radius, surpassing others in the range of attack. We found these strike maneuvers are driven by bilaterally asymmetric deformations of a few legs which rapidly change the functional length and orientation to generate bursts of linear and angular momentums. Also, other legs perform rapid flexions to regulate whole-spider inertia, significantly enhancing the rotational speed. Based on the spider's jointed musculoskeletal framework, we derive a generalized template for body maneuvers driven by leg deformations and highlight the functional significance of jointed, laterigrade legs for enhancing maneuverability.

39.2 ZERA, AJ; University of Nebraska; *azera1@unl.edu*

New insights on the roles of juvenile hormone, ecdysteroids and insulin-like peptides as regulators of wing polymorphism

Juvenile hormone (JH) has been a major focus of studies investigating the endocrine regulation of wing-polymorphism. The most general model postulates a single threshold, above which JH causes the expression of traits that define the short-winged, flightless morph (SW), and below which JH causes the expression of traits that define the long-winged, dispersing morph (LW). Early studies in aphids and crickets produced ambiguous results due to the small size of aphids or to the very low JH titer in nymphal crickets. Detailed studies in adult Gryllus firmus morphs uncovered an unexpected, and novel morph-specific JH titer circadian cycle (cycling in LW but not in SW) in both the laboratory and field. This finding clearly contradicts the classic model. Morph-specific daily rhythms in global gene expression are strongly associated with and are possibly caused by the morph-specific JH titer rhythm. Daily rhythms for hormonal traits and gene expression, which have largely been ignored in studies of life history evolution, may be common, and may play an important role in adaptation. JH likely has evolved a specialized within-morph function in Gryllus, regulating aspects of daily flight in the LW morph, which exhibits circadian flight. Other hormones, such as insulin-like peptides and ecdysteroids exhibit large-magnitude, non-cyclic differences between the morphs. These hormones possibly regulate the expression of chronic (long-term, non-circadian) differences between LW and SW morphs, such as the much greater ovarian growth of the SW, flightless morph, and the much greater biosynthesis of triglcyeride (flight fuel) in the LW morph. Future studies need to investigate JH titers in more detail, and other hormones, most notably peptides and biogenic amines, which, until very recently, have been largely ignored in endocrine studies of wing polymorphism.

P2.166 ZERINGUE, AF*; MIRE, P; University of Louisiana at Lafayette; *afz1859@louisiana.edu*

Hair Bundle Abundance in Nematostella vectensis is Regulated by Delta-Notch

Sea anemones have hair cells bearing hair bundles on their tentacles which are used to detect nearby prey. Hair bundles in sea anemones are similar in morphology and physiology to those in the ears and lateral line system of vertebrates. The Delta-Notch pathway has been implicated in regulating hair cell differentiation in vertebrates. We tested whether this pathway was involved in differentiation of hair cells in adult anemones. We tested three groups of anemones: seawater control, 0.1% DMSO in seawater, and 20uM DAPT in 0.1% DMSO seawater. DAPT is an inhibitor of the Delta-Notch pathway. Anemones were incubated in solutions for 48 h, and then tentacles were excised and processed for phase-contrast microscopy. Hair bundles were counted and surface areas measured from digital images. Hair bundle density was expressed as the number of hair bundles per 50 microns of tentacle surface. Our average hair bundle density for the seawater control was 4.60+1.2, for DMSO control was 4.46+0.8, and for DAPT treatment was 6.86+1.7. There was no statistically significant difference between the seawater control and DMSO control groups, indicating no effect of DMSO alone on hair bundles, but there was a significant increase in hair bundle density when the anemone tentacles were treated with DAPT dissolved in 0.1% DMSO. These results support our hypothesis that Delta-Notch regulates differentiation of cells forming hair bundles in anemone tentacles. Because each hair bundle in anemones is formed from a multicellular complex of 2-4 hair cells surrounding a single sensory neuron, ongoing experiments are investigating whether neuronal density increases with the inhibition of the Delta-Notch Pathway in addition to hair bundle density.

146.5 ZHANG, Y*; HUMES, F; BRASHER, A; KALLENBERG, C; KAVAZIS, A; HOOD, W; ZHANG, Yufeng; Auburn Univ.; *yzz0095@auburn.edu*

The mitohormetic response and an evaluation of a method for inducing oxidative damage

It has been proposed that mitochondria display a biphasic response to reactive oxygen species (ROS) accumulation referred to as mitohormesis. Under mitohormesis, low levels of ROS stimulate protection against oxidative damage, whereas high levels result in the accumulation of oxidative damage. The mechanisms that underlie improved function following low levels of ROS production are poorly understood. We evaluated the changes in mitochondrial performance in house mice following X-irradiation, which induces ROS production. Eight mice were maintained as unexposed controls and 8 mice were assigned to each of 5 groups that varied in time between x-ray exposure and mitochondrial isolation, including 1 hour, 1, 4, 7, and 10 days after x-ray. We measured mitochondrial respiratory function (RCR), ROS production (H_2O_2), and oxidative lipid damage (4-HNE) in the liver and the skeletal muscle from both hind legs and liver. In liver, RCR showed a right skewed U-shape curve in which day 1 and day 4 mice had significantly lower RCR than both non-irradiation control, and all other x-rayed mice. H_2O_2 and 4-HNE in liver displayed inverse U-shaped curves, with both peaking on day 4. Similar trends that were not significant were observe for RCR, H_2O_2 and 4-HNE levels in muscle. These data provide evidence that mitochondria become damaged in response to x-ray, but recover within one week of exposure. This represents the protective effect that ROS exposure has on mitochondrial function. Ongoing measurements of oxidative damage repair, mitophagy, mitochondrial apoptosis, and biogenesis will provide more comprehensive understanding of the mitohormetic response. The value of x-ray in inducing oxidative damage in experimental studies will be discussed.

100.3 ZHANG, C*; POMETTO, S; SANDE, L; BEARD, CE; APRELEV, P; ADLER, PH; KORNEV, KG; Clemson University ; *chengqz@clemson.edu*

Capillary Effect of Saliva on Self-assembly of Butterfly Proboscis

The butterfly proboscis is the feeding organ for acquiring liquid food from a rich variety of sources. It consists of a pair of C-type fibers, called galeae, which are developed separately in the pupa and when the butterfly emerges from it, these two galeae are still separated. The insect uses an evolved process to bring the galeae together, unite and lock them in place. It has been proposed that saliva glues the galeae together. However, recent analysis of rheological properties of saliva showed that it does not possess any visco-elastic properties or sliminess, suggesting that the lepidopteran saliva is almost inviscid and cannot supply the forces needed to hold the galeae together. We hypothesize that the saliva meniscus is used by Lepidoptera to bring and hold the galeae together while locking the legulae in place. In this research, we applied the Micro CT technology to experimentally study the configuration of the liquid bridge formed between the separated galeae. Based on the experimental observations, we constructed a biomechanics model to describe the meniscus configuration in separated galeae. The image analysis of meniscus profiles confirms the model predictions. The model also suggests that the capillary force induced by this meniscus is sufficient to hold the galeae together.

58.5 ZHANG, P*; GOLD, DA; JACOBS, DK; UCLA; *pzhang312@ucla.edu*

DNA Methylation Across Life History Stages of Jellyfish Aurelia (Cnidaria, Scyphozoa)

A major milestone in the evolution of complex multicellularity, division of labor by cell differentiation requires differential gene expression; the underlying epigenetic programs establish and maintain the differential expression through the cell cycle. Methylation of cytosines provides one component of the epigenetic equipment in some metazoans, but not others, and plays an important role in inheritance beyond the level of four bases across generation, and is thus crucial for understanding the evolution of complex multicellularity. Here we examine the complex life history of *Aurelia* a medusa bearing cnidarian, sister to the better studied Bilateral. *Aurelia sp.1* exhibits complexity such as neurosensory organs, and a multistage life history where germ layers undergo complete reorganization and cells dedifferentiate and redifferentiate. To reveal changes in epigenetic programs throughout its life history, we sequenced cytosine methylation by whole genome bisulfite sequencing at various stages of *Aurelia*. We show that methylation is concentrated to CG sites; about 5% of CG sites are methylated in polyp. We also examine developmental genes such as transcription factors in the POU and SIX families that are known to be involved in neurosensory system development, and correlate methylation status with transcription level. We identify highly methylated regions across the genome, and assess these by sequence and gene ontology analysis. Overall, this study provides insight into the epigenetic regulation of gene expression through DNA methylation in a cnidarian that shows complex life history. This strengthens the case for evolutionary loss of DNA methylation in some bilaterians and supports aspects of shared ancestry in DNA methylation of Metazoa.

80.6 ZHAO, M*; GARLAND, T; CHAPPELL, MA; SALTZMAN, W; University of California, Riverside; *mzhao002@ucr.edu*

Effects of an Energetic Challenge on Male California Mice (Peromyscus californicus): Modulation by Reproductive Condition

In female mammals, reproduction changes energetic demands, metabolism, and morphology. In species in which males assist with rearing offspring, reproduction could potentially be associated with metabolic, energetic, and morphological changes in fathers; however, this has rarely been addressed. We examined effects of an energetic stressor on metabolically important physiological, morphological, and behavioral measures, and whether these effects differ between breeding and nonbreeding males, in the biparental California mouse. Males were paired with an ovary-intact female, an ovariectomized female that was treated with estrogen and progesterone to induce estrus, or an ovariectomized female that was not hormone-treated. Within each group, half of the animals were housed under standard laboratory conditions and the other half in cages requiring them to climb wire mesh towers to obtain food and water; in addition, these latter animals were fasted for 24 hours every third day. Based on animals completed so far, males housed under energetic challenge had increased body mass, fat mass, and relative liver mass, along with decreased relative triceps surae mass, compared to controls. The energetic challenge also increased blood lipid content and pain sensitivity. Only relative testis mass showed a reproductive condition x housing interaction: energetic challenge decreased testis mass in non-breeding males, but breeding males were unaffected. We found no other statistically significant differences among reproductive conditions. These results indicate that our energetic-challenge paradigm had numerous metabolic and morphological effects, but that these effects were rarely modulated by reproductive condition.

100.4 ZHOU, Y*; NOEL, A; HU, DL; Georgia Institute of Technology; *alexis.noel@gatech.edu*

Sweating can improve grip in humans

Fingerprints have long been thought to increase friction. In this study, we show that a fingertip's grip is augmented by the hundreds of sweat glands that appear between the grooves of the finger print. As we grip objects, sweat is excreted forming small puddles, whose surface tension forces increase grip. We measure the force and size of the sweat puddles and provide an analytical model predicting the time course of adhesion forces. Understanding how sweat interacts with surfaces may be beneficial to design of prosthetics and interactive electronics such as smartphones.

130.5 ZHU, R*; LEWIS, GT; BART-SMITH, H; Univ. of Virginia; *rz6eg@virginia.edu*

Effects of Peduncle Flexibility on Thunniform Swimming Performance

Thunniform swimming has been recognized as an efficient swimming type for high-speed travelers such as tuna. When tuna swims, the majority of motion happens at posterior one-third of the body, which mainly consists of flexible caudal fin and peduncle with rotational freedom. It has been proven that choosing the optimal flexibility for flapping aerofoil panel or artificial fin can boost the thrust and efficiency by over 100%, due to change in fin kinematics and wake structure. In this study, a free-swimming flow tank set-up will be employed to investigate whether there also exists an optimal peduncle flexibility in terms of swimming performance. An artificial tuna tail with same rigid caudal fin (as the control variable) and peduncles with various rotational stiffness will be tested over a range of frequency (0.5-2.5 Hz) at constant angle amplitude (30 degrees). Steady swimming speed and torque input will be measured for evaluating thrust generation and cost of transportation. The steady swimming states will also be video recorded for kinematic analysis and study of fluid-structure interaction.

114.1 ZHUANG, MV*; RUSSELL, AP; JAMNICZKY, HA; HIGHAM, TE; Univ. of California, Riverside, Univ. of Calgary; *mzhua001@ucr.edu*

Evolution of the gecko ankle in relation to the acquisition of frictional adhesion: A geometric morphometric analysis of the mesotarsal joint

Among terrestrial vertebrates, foot morphology and locomotor function are closely associated. A prominent example of this is the pedally-based adhesive system of geckos. Although the integumentary aspects of this complex are well-studied, its skeletal elements are not. The mesotarsal ankle joint of limbed squamates, situated between the astragalocalcaneum and fourth distal tarsal, is complex and governs the patterns of foot motion during propulsion. Among geckos, pad-bearing taxa have different limb and ankle kinematics from ancestrally padless forms, and we predicted that such kinematic differences are reflected in skeletal anatomy. To explore whether evolutionary changes in the morphology of the ankle joint have accompanied the acquisition of adhesive function, we obtained 3D micro CT images of the hind foot of 28 genera of the Gekkonidae and six outgroups. Our sample represents seven origins of the adhesive apparatus. We used 3D geometric morphometrics and phylogenetic comparative methods to compare shape variation in the ankle joint among ancestrally padless and pad-bearing lineages. Preliminary results suggest that the ankle joint of pad-bearing lineages differs from that of ancestrally padless lineages in having a shallower astragalocalcaneal groove and a shorter ventral peg on the fourth distal tarsal. This is suggestive that flexion and rotation of the crus about the foot are decoupled in pad-bearing lineages. Our results have important implications for the function of the adhesive system and gecko locomotion, and also provide evidence relating to how superficial and deep anatomy change in parallel in association with function.

115.6 ZIMMER, C*; TAFF, CC; SCHECK, D; VITOUSEK, MN; Cornell University, Ithaca, NY; *cgz8@cornell.edu*

Effects of predator type and proximity on glucocorticoid level

The fear of predators can have a wide-range of effects on the behavior, physiology, fitness and demography of animals. One of the primary mechanisms that mediate these effects is considered to be predator-induced changes in glucocorticoid levels. Despite the widespread belief that exposure to predators triggers the physiological stress response, very few studies have measured glucocorticoid responses to predator presence in natural conditions. Among those that have, the results are not consistent, suggesting that the nature of the predator and/or the perception of the predator as a threat could have a significant impact on whether an individual mounts a glucocorticoid response. However, the effects of different predator types or proximities have not been systematically tested in any study. We studied the glucocorticoid response to acute predator exposure in breeding female tree swallows (*Tachycineta bicolor*). To test the role of predator type in inducing a physiological stress response we compared the glucocorticoid response to raptor mounts (common kestrel: *Falco sparverius* and sharp-shinned hawk: *Accipiter striatus*) and mink mounts (*Neovison vison*) presented outside the nest box, with samples collected from non-predator exposed females. To assess the effect of predator proximity we compared the glucocorticoid response to mink mounts presented outside the nest box with those presented inside the box, along with paired controls. Our results suggest that predator exposure does not universally induce a glucocorticoid stress response, but that the nature of predator exposure matters. These findings have implications for understanding the physiological effect of predator exposure in natural systems, as well as for experimental studies that attempt to manipulate physiological stress through predator exposure.

P2.71 ZOGBAUM, LILY*; ALBERTSON, CRAIG ; Bryn Mawr College , University of Massachusetts ; *lzogbaum@brynmawr.edu*

Genetic Basis of Cichlid Pharyngeal Jaw Divergence: A Microhabitat Perspective

The pharyngeal jaw (PJ) apparatus is important for prey processing in fishes, and variation in this structure is associated with species divergence into distinct foraging niches. Differences in PJ shape are typically studied within the context of broad ecological niche-shifts (e.g., molluscivore vs piscivore). Comparatively little is known about patterns of variation in this structure within a foraging niche. In this study, we examined PJ morphology in two herbivorous cichlid species from Lake Malawi, *Labeotropheus fuelleborni* (LF) and *Maylandia zebra* (MZ). We detected measurable differences for a range of PJ traits, which suggests that species with broadly overlapping diets have distinct PJ shapes. We next assayed the same phenotypes in an F2 population generated from crossing LF and MZ, which enabled us to genetically map loci associated with variation in PJ shape (i.e., QTL analysis). In total, 42 QTL were detected. For most QTL the allele effects were in the expected direction, which is consistent with PJ evolution via divergent selection. There was also a fair amount of overlap between QTL for different PJ traits, including at least two "hotspots". One of these hotspots contains the regulatory gene, ptch1, which has been previously associated with oral jaw divergence between LF and MZ. In all, we find that subtle PJ shape variation has a tractable genetic basis, which may allow for future investigations into the molecular mechanisms that underlie divergence in this important trait.

62.7 ZOLLINGER, S*; DORADO CORREA, A; HEIDINGER, BJ; BRUMM, H; Max Planck Inst. for Ornithology, North Dakota State Univ.; *zollinger@orn.mpg.de*

The effect of traffic noise exposure on telomeres varies with developmental stage

The effects of anthropogenic noise on animals have been a topic of increasing concern over the past decade. Many studies have focused on the effects of traffic noise on vocal signaling in animals, but less is known about whether traffic noise has non-acoustic, detrimental effects on exposed individuals. Noise pollution is one of the leading environmental health risks for humans, and is linked to a myriad of stress-related health problems. Yet little is known about the long-term effects of noise on the health and fitness of wildlife. We investigated direct and cross-generational effects of noise exposure on telomeres, a measure of cellular ageing that is predictive of disease and longevity in humans and other organisms. To test this, we bred zebra finches, *Taeniopygia guttata* in three different noise treatments: 1) parents and their young nestlings were exposed to traffic noise, 2) older offspring that had already left the nest were expose to traffic noise, and 3) neither parents nor offspring were exposed to traffic noise, and examined the effects on offspring telomere length and loss rate. We found that exposure to traffic noise increased telomere loss in older offspring. However, there was no significant effect of parental or early offspring exposure to traffic noise on offspring telomere length or loss rate. These age-dependent differences in telomere loss could occur if parents buffer younger offspring against the detrimental effects of noise exposure and/or if younger offspring are less sensitive to noise pollution. In conclusion, our data highlight the need to consider the developmental stage of an organism as well as parental effects to better understand the ecological consequences of anthropogenic change.

P2.34 ZOLLINGER, S*; DORADO CORREA, A; GOYMANN, W; BRUMM, H; Max Planck Inst. for Ornithology; *zollinger@orn.mpg.de*

Effects of experimental traffic noise exposure on stress physiology, immune function, and reproductive success in birds

Since the dawn of the Anthropocene epoch, anthropogenic noise levels have dramatically risen in terrestrial and aquatic habitats. As urbanization and noise levels rise, investigations into the impacts of noise become more and more important. The WHO has identified noise pollution as one of the leading environmental health risks in humans, and chronic noise exposure is linked to a myriad of non-acoustic, short- and long-term health and psychosocial effects in humans. However, less is known about non-acoustic effects of anthropogenic noise exposure on animals. We investigated long- and short-term effects of traffic noise exposure on zebra finches breeding in small group aviaries, using a repeated measures design. Birds were allowed to breed in both noise, and no-noise conditions, and then we measured a range of behavioral, physiological, and reproductive parameters. As noise is a known cause of physiological stress responses in humans, we examined whether chronic noise exposure has effects on plasma glucocorticoid levels at different stages of the breeding cycle in. We also investigated whether chronic noise impacted immune function, as measured with a bacteria-killing assay, and heterophil to lymphocyte (H/L) ratios, a common measure of chronic stress in birds. Finally, we will present data on the non-acoustic effects of traffic noise exposure during the courtship, nesting, and nestling care periods on reproductive success, frequency of extra-pair paternity, current condition (measured as body mass) and offspring growth rates. The expected results will fill a crucial gap in our understanding of the impact that global anthropogenic change may have on different systemic levels in a model animal.

P3.235 ZSOLDOS, RR*; VOEGELE, A; VALENTIN, S; WEBER, A; LICKA, TF; University of Natural Resources and Life Sciences Vienna, University of Bonn, University of Edinburgh, University of Veterinary Medicine Vienna ; *rebeka.zsoldos@boku.ac.at*

Comparative Study on Equine and Ovine Gluteus Medius Muscle Activity Pattern During Treadmill Trot

From a dynamic perspective, terrestrial mammals of very different sizes move in a similar way as they have very similar Froude numbers, even though the dynamic properties of the tissues such as muscle do not change with the different sizes. In the present study we investigated the difference between the muscle activity patterns of the superficial gluteus medius muscle (GM) of the horse (*Equus caballus*) and the sheep (*Ovis aries*) during trotting on a treadmill. Surface electromyography and simultaneous kinematics recordings were used and stance and swing phases as well as the corresponding muscle activities were recorded. Horse and sheep showed similar overall mean activity patterns, however the phase ratio between stance and swing phase activities were 2.5 time higher in sheep then in horses. Previous work showed that toe-limit strains percentages were almost three-fold higher in equine superficial digital flexor tendons than in ovine plantaris muscles. The distortion required to make up for this could occur at the documented muscular level, as the larger mammals (i.e. the horses) stiffen their limbs more and have their muscle activity peaks later in the motion cycle than the sheep, where the earlier peak activity contributed to the muscle phase ratio difference between the species. The results of the present study show that even within the group of the ungulate mammalians differences in size and in limb design require different muscle activity patterns for an (outwardly) very similar gait such as trot; and that stance and swing phase alterations compensate for such differences.

19.6 ZUAZO, CE*; BENNETT, S; KAPAN, D; California Academy of Sciences; *czuazo@berkeley.edu*

Home Is Where the Gut Is: Variation Among Mosquito Species and Their Endosymbionts Across Different Habitats

Mosquitoes are infamous for their role as the most significant vector for infectious diseases that affect human health. They transmit pathogens such as those that cause dengue and dengue hemorrhagic fever, and zika fever. Their ability to transmit pathogens and propagate viral genes has been shown to be influenced by the diversity of their microbiota (communities of bacteria, viruses, and fungi). One bacterium in particular, Wolbachia, has been shown to inhibit the ability to transmit dengue. In order to gain insight on their ecological and evolutionary relationships, we investigated how mosquitoes and their inhabitants vary across species and habitats. This is especially important in zones where medically important pathogens are endemic, such as areas of recent dengue and zika outbreaks in Hawaii. We collected hundreds of mosquitoes along an environmental gradient on the Big Island of Hawaii, from which about a dozen mosquitoes were chosen for analysis. These representatives were homogenized and their total RNA extracted and microbiomes characterized using Next-generation sequencing by Miseq. By randomly fragmenting and amplifying the contents of the homogenized sample, we were able to create a snapshot of the communities within each mosquito and further elucidate relevant microbial interactions.

19.4 ZYLBERBERG, M*; VAN HEMERT, C; DUMBACHER, JP; HANDEL, CM; TIHAN, T; DERISI, JL; University of California, San Francisco; California Academy of Sciences, US Geological Survey, California Academy of Sciences, University of California, San Francisco, University of California, San Francisco; Howard Hughes Medical Institute; *maxinezylberberg@gmail.com*

Applying Metagenomic Sequencing to Search for the Cause of an Elusive Avian Disease: Avian Keratin Disorder in Black-capped Chickadees

Avian keratin disorder (AKD), characterized by debilitating overgrowth of the avian beak, was first documented in black-capped chickadees (*Poecile atricapillus*) in Alaska. Subsequently, similar deformities have appeared in numerous species across continents. Despite the widespread distribution of this emerging pathology, the cause of AKD remains elusive. As a result, it is unknown if suspected cases of AKD in the afflicted species are causally linked, and the impacts of this pathology at the population- and community-level are difficult to evaluate. We apply unbiased, metagenomic next-generation sequencing to search for candidate pathogens in birds affected with AKD. We identify and sequence the complete coding region of a novel picornavirus, which we are calling Poecivirus. Subsequent screening of 26 AKD-affected black-capped chickadees and 17 control individuals for the presence of Poecivirus revealed that 26/26 (100%) of AKD-affected individuals were positive, while only 4/17 (23%) of control individuals were infected with Poecivirus. Individuals of other species with AKD-consistent pathology, including two northwestern crows (*Corvus caurinus*), and two red-breasted nuthatches (*Sitta canadensis*), also tested positive for Poecivirus. We suggest that Poecivirus is a candidate etiological agent of AKD.